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ARS National Research Program

NRP NO. 20380 Production of sheep and other animals

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This document [illegible] (ARS-NRP's) or one of the ARS Special Research Programs ([illegible]). These programs provide the basic plans for research in the Agricultural Research Service. The ARS-NRP's and the ARS-SRP's are a part of the ARS Management and Planning System (MAPS). The plans identify national research objectives, describe methods for achieving these objectives, and provide the accounting and reporting system by which these program areas are planned and managed.

Each of the ARS National Research Programs and Special Research Programs outlines a 10-year plan that describes current technology and new technology expected in the 10-year period. The plan includes approaches to research and benefits expected to result from new technology. The Special Research Programs facilitate research planning and management in those exceptional circumstances where special funds are involved or a different kind of research management is needed. They provide the same general type of information as the ARS-NRP's. Both types of research programs were prepared by the National Program Staff with the cooperation of Regional Staffs and Line Managers, Technical Advisors, Research Leaders, and other scientists.

These research plans will be used for a variety of purposes. They serve to link ARS research projects to major program areas involving several agencies within the USDA program structure. ARS-NRP's and ARS-SRP's identify important national problems and describe plans for achieving technological objectives. They provide justifications for current research activities and the basis for funds for future research. They serve as the basis for program reports and for the Agency's accounting system. They also improve the communication between scientists and management, between research managers and staff scientists, between ARS and other research organizations, and between USDA and other departments, the private sector, and Congress.

These documents are dynamic statements of ARS research plans and, as new knowledge is developed, they will be continually updated to reflect changes in objectives and research approaches.

ARS-NPS No: 20380
USDA Program No: 22-678

PRODUCTION OF SHEEP AND OTHER ANIMALS

Technological Objectives:

1. Improve efficiency of reproduction.

2. Improve efficiency of feed utilization

3. Improve genetic capacity for production.

4. Improve management practices and systems.

5. Improve efficiency of producing quality products.

6. Decrease losses from diseases, pests and other hazards through production practices.

Cross Reference by Technological Objective to Other NRP's:

TO 1	NRP	20350	Dairy Production
		20360	Beef Production
		20370	Swine Production
	SRP		Tropical and Subtropical Research
TO 2	NRP	20100	Forage Crops Production
		20110	Improved Practices for Range
		20350	Dairy Production
		20360	Beef Production
		20520	Technologies for Food and Feed Uses - Field Crops
		20530	Technologies for Food and Feed Uses - Animal Products.
	SRP		Tropical and Subtropical Research
TO 3	NRP	20360	Beef Production
		20460	Diagnosis and Control of Foreign Animal Diseases
	SRP		Tropical and Subtropical Research
TO 4	NRP	20110	Improved Practices for Range
		20360	Beef Production
		20400	Livestock Structures and Equipment
		20440	Control of Sheep and Other Animal Diseases
		20470	Toxicology and Metabolism of Agricultural Chemicals and Poisonous Plants
		20480	Control of Insects Affecting Livestock
		20520	Technologies for Food and Feed Uses - Field Crops
		20530	Technologies for Food and Feed Uses - Animal Products
		20790	Preventing Pollution and Improving the Quality of Soil, Water and Air
	SRP		Tropical and Subtropical Research

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PRODUCTION OF SHEEP AND OTHER ANIMALS

I INTRODUCTION

The research objective is to increase production, efficiency of production and desirability of sheep and its products, along with other ruminants, from renewable feed and forage resources, and at the same time permit an adequate return to the producer that is equal to or greater than from any other use of the resources and similarly with other animals.

The American Sheep Industry reached a peak in World War II, declined somewhat following the War, remained stable in the 50's and then declined rapidly since 1960. The early part of this rapid decline seemed to be due to the feeding of surplus grain that depressed the prices of meat and meat animals. Farm prices of lambs were depressed below calf prices and calf production was the main alternative to lamb production. Then as the difference between calf and lamb prices disappeared in the mid 60's the increasing losses from restricted predator control resulted in a continued decline in sheep farms and sheep numbers (Terrill, J. Anim. Sci. 41:276, 1975). The upward trend in losses to predators began even before 1950 and still continues at unprecedented high levels. The declining numbers seemed to result in greater inefficiencies in marketing and processing sheep products as shown by a widening spread between live lamb prices and retail meat prices (P&SA Res. Report No. 2, 1973). Thus both retail and live prices for lambs were depressed below beef and calves and far below the inflation index of all goods and services from about 1958 to 1966. An upward trend in retail lamb price began in 1966 but live lamb price did not begin an upward trend until 1972 and then at a slower rate than inflation.

Increasing losses of sheep and lambs from predators have been the predominate cause of the decline of the sheep industry since about the mid 60's. The reducing supply of slaughter lambs has resulted in depressed farm lamb prices that has affected lamb production over the entire United States and has contributed to the continued decline. Lamb prices are rising now so that they may offset the depressing effect of predator losses sometime in 1976 or 1977 if surplus grains do not reoccur.

The efficiency of lamb meat production increased from 30 lb. of sheep meat per ewe in 1950 to almost 40 lb. in 1972. Decline since 1972 seems due to predator losses. The United States ranks high among countries of the world in efficiency of lamb meat production (Terrill, J. Anim. Sci. 41:283, 1975). Efficiency of meat production by range sheep is about equal to corn and soybeans in energy produced of that expended (Cook, Nat'l. Wool Grower, May 1975). Spedding and Walsingham (Span 18:7-9, 1975) in England reported

that lowland fat lambs required about 2.9 times as much support energy for protein as dairy cows on permanent pasture. Beef cattle as 18-month-old grass fed calves required about 1.5 times as much as lambs. However, sheep plus wool ranked only slightly above single suckled beef and eggs and well below broilers, milk and rabbits in efficiency of protein production (Large, The Biological Efficiency of Protein Production edited by J. G. W. Jones, Cambridge University Press, 1973). Bowman in the same publication on efficiency of conversion of dietary protein to muscle protein shows lambs above beef, equal to veal, but lower than pigs and chickens. Sheep produce meat efficiently because of their high prolificacy, short growing period and the high quality of meat produced largely on natural forages. Sheep will tend to increase in efficiency because they can be changed relatively rapidly by selection. Also a wide array of technology from research for increased efficiency of sheep is becoming available now. This technology can be improved and expanded by further research.

Food producing animals, particularly, goats and rabbits will probably increase somewhat similarly to sheep as they are able to produce food and other products more economically than many other sources. Domestic fish may become a more important source of food as ocean fish supplies and foreign competition cause a decline. However, fish require high quality feed that is also increasing in cost. Research with these animals would increase their usefulness to the people and also would increase the extent to which they might be utilized as cheaper sources of food.

Mink produce a luxury product primarily from byproduct feedstuffs that are not used by man. The mink industry may remain viable to utilize these byproducts but may not grow because of increasing competition with pets and humans for feed, because of foreign competition, and also because of the high cost of fur products and the reluctance of some to wear animal furs.

Production of other animals such as horses and pets for recreation, and laboratory animals fill special but minor essential needs as related to the total livestock industry. Horses may increase in importance as a source of power and for transportation because of accelerating energy costs but the high cost of feed and labor will slow their use for power until energy and material shortages force a radical change in agricultural technology.

II ARS NATIONAL RESEARCH PROGRAM SUMMARY

The research objective is to increase production, efficiency of production and desirability of sheep and its products, along with other ruminants, from renewable feed and forage resources, and at the same time permit an adequate return to the producer that is equal to or greater than from any other use of the resources, and similarly with other animals.

Sheep numbers have declined continuously since 1960. Predator losses have been the predominate cause of the decline although surplus grain for beef cattle also contributed to the shift from sheep to beef cattle. The primary effect of predator losses was through a reduction in number of sheep farms. The resulting reduction in sheep numbers had a depressing affect on the farm price of lambs because competition for the purchase of slaughter lambs declined along with reduction in slaughter outlets. Lamb prices have been recovering since 1971 but at a slower rate than inflation.

Sheep farmers have increased their efficiency steadily in order to maintain even a low rate of return in the face of increasing losses to predators. Recently new technology such as improvement from selection, a multibreed system of crossbreeding, use of Finnsheep in crossbreeding, breeding ewe lambs, artificial rearing of lambs, better control of parasites and diseases, reduction of losses from poisonous plants, multiple lambing, twice a year lambing, control of time of lambing, pregnancy diagnosis, intensive production, better nutrition, and increase in market weight have become available. Further research is needed on each of these as well as on many other approaches in order to increase the rate of gain in efficiency. Research emphasis on technologies that might have maximum impact on the industry should lead to maximum annual gains although many more than 10 years will be required for ultimate gains.

A Current Technologies

Lambs produced per ewe averaged .98 in 1975 and has increased in recent years from .95 in 1960 in spite of increasing predator losses before docking. Ewes lambing of ewes mated probably averages about 90%. Artificial insemination is generally not practiced because ram semen cannot be stored very successfully. Prenatal lamb mortality probably averages around 20%. Diagnosis of number of lambs in utero is not yet feasible. Neither is control of time of lambing. Reproductive rates are strongly influenced by many environmental factors.

Feed costs have been estimated at \$25 per ewe per year but they are rapidly advancing. Mortality of sheep averages 7.8% and has decreased slightly in recent years in spite of increasing predator losses. Lamb mortality averages 13.8% and has increased steadily since 1954 due to increasing predator losses. Predator losses have tended to mask technological gains in increasing the lambing rate and in reducing mortality.

Slaughter lambs averaged about 104 lb in weight in 1975 as compared with 95 lb in 1950. Days growth to slaughter is not known but probably averages about 165 days and also has probably decreased since 1950. Fleece weights averaged 8.3 lb in 1975 or only slightly above 8.0 in 1940 and 8.2 in 1950. The present average is even below the averages of 8.6 in 1960 and 8.4 in 1970. Fleece weights tend to decrease slightly as lamb production increases. Current technology for management may be described in terms of costs per ewe that total about $50 or about 88% of gross returns. The remaining returns (12%) is for management and capital.

The average live weight of lambs slaughtered in 1975 was 104 lb giving a dressed weight of 51 lb and a dressing yield of 49%. The average fat content of the lamb carcass is about 32%. The yield of boneless, trimmed preferred cuts is about 44%. Lamb meat is generally of acceptable tenderness regardless of age or method of production. Lamb meat may be criticized for being too high in fat, having fat with a high melting point, too small a loin eye area and with cooking odors that are sometimes objectionable. Even though many prefer the lamb flavor, lamb would be more widely acceptable if the characteristic flavor were only slightly perceptible.

Quality of the domestic wool clip approximates an average fiber diameter of 22 microns with a range of 16 to 40. The coefficient of variation averages about 23% with a range of 21 to 27%. Length of staple varies from 1.5 to 5.0 inches with a mean of about 2.5 inches. Crimps per inch varies from 8 to 30 per inch with an average of 16 per inch. Breaking strength of fiber bundles measures about 13 kg with a range of 12.5 to 14.5 kg. Noilage averages about 10:1 with a range of 5:1 to 15:1. Wool with black fibers makes up about 3-5% of the clip while yellow wool makes up about 15% of the clip. Clean yield may vary from 25 to 70% with a mean of about 50%.

The average dairy goat produces almost 11,000 lb milk per year. The average clip of mohair per Angora goat in 1974 was 7.1 lb. Horses for recreation, sport and work are attractive to a great many people but useful information on current technology is not available. Total commercial processing of rabbits for meat is estimated at about 1 million fryers annually. In addition there are from 50 to 100 thousand hobby producers and fanciers who produce another 4 to 8 million fryers. Rabbits are also produced on over 1100 ranchers in 1974. The mink industry is very efficient in utilizing byproducts and wastes from the livestock and poultry industries to produce a high quality product in widely different natural colors. Animals where production information is not readily available include other fur animals, laboratory animals, pets, domestic fish and exotic game animals.

B Visualized Technologies

An increase in the lambing rate from current research by 1985 from .98 to about 1.25 from the current 2.8 SY is expected.

A gain in 7.5% in total efficiency is expected from reducing feed costs by 1985 from the current 2.8 SY of Federal research. This amounts to $.52 per ewe per year or an increase of about 4% in efficiency of feed use. Gains would result primarily from improved use of low cost feedstuffs, improved nutrition for reproduction, better use of nonprotein nitrogen and a better understanding of nutrient requirements.

Visualized genetic technologies are expected to give an increase in efficiency of about 7% in the next 10 years from the current 2.7 SY. Genetic technology has the advantage of yielding annual and permanent gains even though the rate of gain is slow without the long gap between the development of technology and its implementation. Weights of slaughter lambs will probably increase at the rate of about 1 lb per year because some of the needed technology is already available. Improvements projected will largely come from choice of more productive breeds, use of the exotic Finnsheep breed, multibreed crossbreeding and selection.

A reduction in costs of 1% or $.50 per ewe is projected from the .3 SY currently available for management. The savings would probably come about through an increase in efficiency of intensive production and through increased marketing of ram lambs as intact males.

Gains totaling about 7% in efficiency are expected from improvement in the quality of sheep meat from the current 2.85 SY. Gains would result largely from a slight reduction in fat content and an increase in the acceptability of heavy lambs. No gain is expected in wool quality.

Sheep mortality is expected to be about the same in 1985 as at present at an average of about 8%. Increased losses to predators are expected as the coyote population has not leveled off yet and because its territory is increasing. Lamb mortality is expected to increase to about 16% by 1985. Research to reduce coyote losses by reducing the coyote population will probably not be effective before 1985 as technology will need to be perfected and proven before it can be put into practice. Research on other technology to protect lambs from predators will probably only prevent a more rapid increase of predator losses.

Similar gains under each technological objective could be made with other animals if research could be initiated.

C Consequences of Combined Visualized Technologies

The main effect of the increase in efficiency of sheep production will be a reduction in the cost of meat and wool to consumers. Also farmers should receive some increase in their net returns. The

supply of both lamb and wool should increase so that more of each should be available to provide food and fiber to a larger share of the world's population. The expected increase in efficiency should permit these products to be exported at prices people in food and fiber deficient countries could afford to pay. It is expected also that the research would increase the use of little used or unused natural resources in the form of low quality forages, crop residues and wastes. Increased utilization of wastes as feed would reduce pollution and improve the environment. It might also lead to harmful residues in food and to imbalances in sheep feed that would require additional research.

The consequences of technology for improving the quality of sheep meat and wool will include an increase in the value of the products to the consumer. The relative cost of the products may be reduced on the one hand while the willingness of the consumer to pay a higher price is enhanced on the other. Improved quality should lead to a greater demand for and consumption of lamb meat and wool.

Any reduction of the coyote population will be of benefit to the public through increased efficiency of meat production and through enhancing wildlife, game animals and birds and endangerd species.

Similar consequences to those for sheep will result from similar research on other animals.

D Total Potential Benefits and E Total Research Effort

These two sections have been combined in the following tabulation.

A total of 13.2 SY from ARS sheep production at a cost of $2.2 million should give a net return of $23 million annually by 1985. Gains were calculated in such a way as to avoid double counting. Net returns have probably tripled above the values used in this NRP by an increase in the farm price of lamb just while this NRP was being written. These prices probably will come down as the supply of lamb increases but an increase in efficiency over a period of several years might permit the farmer to retain the increased rate of return. An increase in research effort from 13 to 56 SY should increase the expected efficiency or net returns to 127% and $83 million annually.

An increase effort of 7 SY on goats, 2 on horses, 3 on rabbits, and 2 on mink or a total of 14 SY on other animals would help these minor industries reach a much higher level of usefulness to the consumer but benefits have not been quantified. Additional research on other fur animals, laboratory animals, pets, domestic fish and exotic game animals by ARS can probably not be justified by ARS at this time.

NOTE: The expanded support level reflected in this National Research Program represents staffs views as to the additional level of staffing that can be effectively used in meeting the long-term visualized objectives for this program. These do not reflect commitments on the part of the Agency.

TO	Current research input			Expected gains in net returns by 1985 with current research input		Recommended expanded research input	Expected gains in net returns in 10 years with expanded input	
	ARS		SAES					
	SY	$ 1/	SY 2/	%	$ million	SY	%	$ million
1. Improve efficiency of reproduction	2.8	457,148	18.2	13	8.5	10	47	30.7
2. Improve efficiency of feed utilization	2.8	457,149	21.1	7	4.6	8	17	11.1
3. Improve genetic capacity for production	2.7	440,822	7.0	7	4.6	10	23	15.0
4. Improve management practices and systems.	.3	48,980	6.0	1	.7	7	16	10.5
5. Improve efficiency of producing quality products	.6	97,960	2.3	5	3.3	5	14	9.1
6. Decrease losses from diseases, pests and other hazards through production practices	4.0	653,069	- 3/	2	1.3	16	10	6.5
Total	13.2	2,155,129	54.6	35	23.0	56	127	82.9

1/ Approximate allocation of funds to TO's.
2/ 1973 Allocation.
3/ Included under NRP 20440 Control of Sheep and Other Animal Diseases.

III TECHNOLOGICAL OBJECTIVES

The calculation of gains in efficiency of sheep production from research is shown in Appendix I. In general, gains were calculated from 1975 and are given for 1985 or a 10 year period.

An explanation of possible ecosystem, sheep production areas, and the benefits expected from this strategy for sheep research and production is given in Appendix II.

Statistics of sheep production to show the characteristics of the industry and available information on traits related to efficiency of production are given for past years in Appendix III. Statistics are all taken from Statistical Reporting Service reports. These will be added annually to show progress and to serve as a monitor of research gains. Additional background statistics will also be included as they become relevant.

III.1 Improve Efficiency of Reproduction

A Current Technology

Reproductive efficiency is affected by almost every technology of sheep production so that technology here is generally confined to reproductive techniques such as pregnancy diagnosis, artificial insemination, artificial induction of estrus, ovulation and parturition. Mating ewe lambs, pregnancy diagnosis, synchronization of estrus and induction of ovulation are the only practical techniques available at the present time and all require more research for full implementation.

Reproductive efficiency is best measured by lambs produced per ewe although this trait is very complex and is dependent on many different factors. Lambs produced per ewe (born or docked) have been increasing from .93 in 1969 to .98 in 1975 in the U.S. Increases in different areas have varied from .76 to .87 in the Southeast to 1.07 to 1.16 in the Mideast, respectively. Increases have been slower in the Intermountain area and surrounding areas where coyotes are taking lambs before docking counts are made. The corresponding increase for the Intermountain area was .91 to .92. However, these increases may be due more to breeding and selection than to reproductive techniques.

Fertility, or ewes lambing of ewes mated, probably averages about 90% and the reduction from 100% is probably equally divided among rams and ewes. A few farmers are producing more than one lamb crop per year but the average is very close to one lamb crop per year. Techniques to breed out of season and during lactation need improvement.

Ram semen can be stored frozen but low fertility generally results. The ability to store ram semen and present techniques of artificial insemination do not permit ready application by farmers. Likewise the easy detection of estrus and ovulation is not possible. Adequate techniques of synchronizing both time of ovulation and time of lambing are not yet available. Prenatal mortality seems to result in about a 20% reduction in fertility. Diagnosis of pregnancy while quite feasible now might be improved to obtain high accuracy early in pregnancy and also to permit determination of the number of fetuses present. Mating of ewe lambs is feasible now but increased success with higher lambing rates would increase its contribution to increased efficiency.

Reproductive rates are influenced by many environmental factors, some unknown, but principally extremes of temperature, storms, sudden changes in weather and variation in day length. A better understanding of how these factors act might lead to improved management techniques.

The control of sex of the offspring to the extent that a high majority of males or females could be obtained at will would have practical benefit because some farmers produce entirely slaughter lambs where males are more efficient while others produce largely replacement stock where females are desired.

B Visualized Technology

An increase in the lambing rate of slightly less than 1% from improvements in fertility of both males and females is expected from the current 0.5 SY.

Improvements in lambing rate by reproductive techniques by increasing both the number of lambs per birth and the lambing frequency is expected to increase the lambing rate by 24% from .98 to 1.22 from the current 1.7 SY while an increase to a lambing rate to 1.31 might be expected from the recommended 3 SY. These gains would be additive to the gains expected from genetic and management research. Calculation of estimated gains is shown in Table 1.

There is no current research effort on storage of ram semen, improvement of artificial insemination, and detection of estrus and ovulation but the addition of the recommended 1.2 SY would give about a 2% gain in lambing rate from .98 to 1.0. Improvement of these techniques would accelerate gains from breeding and management and in the control of lambing time that are not claimed here.

The practice of storage and transplantation of embryos could not be expected to increase the lambing rate with the .05 SY now on hand and only slightly with the .2 SY recommended. However, the technique would be useful experimentally.

Reduction in prenatal mortality may not be too important in sheep because fecundity can be increased so readily. The 0.2 SY both on hand and recommended could probably not increase the lambing rate perceptibly in 10 years.

Successful synchronization of ovulation and lambing time would have a marked effect on efficiency of production because they would facilitate other breeding and management gains. There is no current effort on these techniques but the 3 SY recommended would probably lead to a gain from .98 lambs per ewe at present to 1.48. Calculation of the gain was simplified by applying it to lambs born although an appreciable part of the gain would result from a reduction of mortality near lambing time. This gain is additive to other gains in lambing rate.

Diagnosis of pregnancy does not have a direct effect on reproductive efficiency except that it reduces the cost of maintaining nonpregnant ewes and thus increases the lambing rate by reducing the number of ewes that fail to lamb. An imperceptible gain is expected from the .1 SY working now; the lack of gain is partly due to the progress already made even though only implemented to a small extent but also to the low current effort. The recommended effort of .6 SY would lead to an increase from .98 to 1.00 in lambing rate. Diagnosis pregnancy is also involved in TO 4, Improve management practices and systems.

Increased mating of ewe lambs will lead to marked increases in efficiency but much of the research is already done and will be more fully implemented over the next few years. Additional research recommended would increase the lambing rate from this technology only very slightly but might be helpful in increasing the implementation of research completed.

Effects of improvement of techniques to reduce the detrimental effect of environment on the lambing rate from current and recommended research of .2 SY would not give a perceptible gain in 10 years. Still this is an important problem and deserves attention even though more than 10 years are required for perceptible gains.

Control of sex receives no research attention now. A gain in total efficiency of 2.5% would be expected from application of 1 SY to this problem. The gain would arise from the ability of the farmer to produce a higher proportion of the sex of lamb that would have a greater effect on his net returns.

C Research Approaches

(1) Reduce infertile ewes: Investigate physiological means to increase ewe fertility.(NCR, Clay Center, NE).

(2) Improve ram fertility: Study physiological measures to facilitate production and maintenance of more fertile rams (NCR, Clay Center, NE).

(3) Increase multiple lambs: Physiological methods, largely through use of exogenous hormones or related materials have been used to increase the number of ovulations and number of lambs per lambing including super ovulation techniques. Perfection of these techniques might permit an increase to 4 lambs per lambing where such might be useful. A gain of only one lamb per ewe for the entire country is estimated (NCR, Clay Center, NE; WR, Dubois, ID). Also see III. 3. Improve genetic capacity for production.

(4) Increase lambing frequency: Study physiological methods, largely through use of exogenous hormones, to permit practical twice-a-year lambing and other frequencies more often than once per year. Breeding out of season and during lactation are included as well as hastening involution of the uterus (NCR, Clay Center, NE; WR, Dubois, ID). Also see III.3 Improve genetic capacity for production.

(5) Store ram semen and improve AI: Develop techniques for successful long period storage of ram semen and artificial insemination under various conditions. Improve techniques for collection and evaluation of ram semen and for its introduction into the ewe to obtain high fertility from a single insemination (None).

(6) Detect estrus: Develop techniques for detecting estrus and ovulation in ewes in a practical way so that controlled breeding or more efficient mating, either natural or artificial, can be practiced under any situation (None).

(7) Store and transplant embryos: Develop physiological techniques for preservation and transfer of embryos to facilitate genetic practices (None).

(8) Reduce prenatal mortality: Develop physiological techniques to reduce mortality between conception and birth including failure of conception and dead lambs at birth (WR, Dubois, ID). Also see NRP 20440, Control of Sheep and Other Animal Diseases.

(9) Synchronize ovulation: Synchronize ovulation and/or estrus so that controlled numbers and large numbers of ewes can be successfully mated either naturally or artificially at any designated time (None).

(10) Control lambing time: Synchronize time of lambing so that any designated number of ewes can be lambed within a predetermined period of time (None).

(11) Diagnose pregnancy: Improve methods of practical detection of pregnancy and determination of number of fetuses at any stage of gestation (WR, Dubois, ID). See TO 4, Approach 11.

(12) Increase mating of ewe lambs: Reduce age of puberty and develop physiological procedures for more successful lamb production from ewe lambs without high levels of nutrition (None).

(13) Environment and reproduction: Study the effect of light, sound and other environmental factors on reproduction and behavior to develop techniques to enhance reproductive efficiency and to reduce detrimental effects (NER, Ithaca, NY; WR, Dubois, ID). Also see NRP 20400 Livestock Structures and Equipment.

(14) Control sex: Develop physiological methods of treating females or semen to control the sex of offspring to be born or to regulate the proportion of each sex of lamb to be born (None).

D Consequences of Visualized Technology

The increase in efficiency of sheep production from application of reproductive techniques will increase net returns to farmers and at the same time reduce the cost of meat and wool to consumers. It is expected also that the supply of both lamb and wool will increase as a result of this increased efficiency and more of each should be available to provide food and fiber to a larger share of the world's population. The expected increase in efficiency should permit these products to be exported at prices people in food and fiber deficient countries could afford.

E Total Potential Benefits

The gain in efficiency of the sheep industry of 13% in 10 years from improvement of reproductive techniques would result in an increase in production of about 5 pounds of meat per ewe and an increase in annual net returns to farmers, middlemen and consumers of about $.91 per ewe or $8.5 million for the present ewe flock. The increased efficiency would tend to reduce retail prices.

F Research Effort

1 Current Level

The current research effort on reproduction of 2.8 SY at Ithaca, Beltsville, Clay Center and Dubois is inadequate to achieve an appreciable proportion of the opportunity to improve the efficiency of the sheep industry. The 18.2 SY at State experiment stations helps make up some of the deficiency but the total effort is still inadequate. The present small size of the industry may not justify more research but the opportunity for reproduction research to further increase efficiency and to stimulate the growth of the industry should be considered. The increasing cost of grain production and the need of the other meat animals and poultry for much higher proportions of grain in their diets

than sheep indicate that sheep meat may be able to compete better in the future because of the lower requirement of sheep for grain. Thus an increasing supply of sheep meat might offset some of the decrease in meat consumption that will likely follow the higher cost of grain fed meat.

2 Expanded Level

An increase of ARS research of 7.2 SY (2.8 to 10) is recommended. About 72% of the additional effort would be applied to important approaches that now receive no Federal or State attention. The remainder would be used to strengthen research already underway.

III.2 Improve Efficiency of Feed Utilization

A Current Technology

Feed costs have been estimated at $25 per ewe per year. These have been based on the assumption that ewes are maintained and reproduce largely on natural range and pasture with minimum use of harvested forages. Grain or concentrates would be fed only in late pregnancy and early lactation and in some cases to growing lambs. While costs have been calculated on a ewe basis these include the feed required to produce market lambs or replacement rams or ewes. They also include feed for nonproducing rams or ewes that may be on hand. Feed costs will increase as lambs per ewe increase but returns will also increase. Savings from lower feed cost per unit of production will still be valid. However, gains in feed efficiency through increased reproductive rates to shift feed use from maintenance to growth has been included under reproduction and in each other technology as increased output in relation to cost.

B Visualized Technology

A gain of 7.5% in total efficiency is expected from reducing feed cost by 1985 from the current 2.8 SY of Federal research. This amounts to $.52 per ewe per year or an increase of about 4% in efficiency of feed use. Gains would result primarily from increased use of low cost feedstuffs, through a better understanding of nutrient requirements, better use of non-protein nitrogen, and better reproduction on low quality feed through more efficient use and through better use of supplements. Calculation of estimated gains is shown in Table 2.

C Research Approaches

1 Nutrient requirements: Determine nutrient requirements for each aspect of growth and maintenance including assessment of nutritive status. Reduce amount of feed required through ruminant nutrition studies. Determine optimum combinations of protein, energy, mineral and other ingredients along with synergetic effects (NCR, Clay Center, NE).

2 Feed supplements: Determine optimum supplements and supplemental methods for maximizing use of natural forages, crop residues and wastes (None). See NRP 20360 Beef Production.

3 Feed additives: Develop feed additives along with hormonal and biochemical means of increasing efficiency of feed use (None). See NRP 20360 Beef Production.

4 Range nutrition: Develop nutritional practices suited to the various range regimes of using various kinds of natural forage as related to range management (WR, Dubois, ID). See NRP 20100 Forage Crops Production, 20110 Improved Practices for Range.

5 Nutrition for reproduction: Determine nutrient needs for each aspect of reproduction and develop methods of increasing reproductive efficiency through nutrition (NCR, Clay Center, NE; WR, Dubois, ID). See III.1 Improve Efficiency of Reproduction.

6 Low cost feedstuffs: Determine which harvesting or industrial byproducts and wastes can be used for sheep at lower cost than conventional feedstuffs and develop practical methods of using them (None). See NRP 20520 Technologies for Food and Feed Uses - Field Crops.

7 Feed intake: Develop more precise measures of appetite and factors affecting it to determine the relationship of these factors to feed efficiency (NCR, Clay Center, NE).

8 Efficiency indicators: Improve methods of measuring feed efficiency for reproduction, growth and maintenance and determine relationships of various physiological measures to feed efficiency (None).

9 Nutrient recycling: Study physiological process as responsible for incomplete use of nutrients to determine how more complete use can be obtained (None).

10 Nonprotein nitrogen: Improve use of nonprotein nitrogen in reducing feed costs (NCR, Clay Center, NE). See NRP 20360 Beef Production.

11 Body composition: Determine nutritional effects on body composition under different environmental situations (NCR, Clay Center, NE). See NRP 20530 Technology for Food and Feed Uses - Animal Products.

12 Feed processing: Determine effects of harvesting, processing and storing feed on efficiency of its use by sheep to develop more efficient practices (None). See NRP 20400 Livestock Structures and Equipment.

D Consequences of Visualized Technologies

The increase in efficiency of sheep production through reduction in feed costs will increase net returns to farmers and at the same time reduce the cost of meat and wool to consumers. It is expected also that the research would increase the use of little used or unused natural resources in the form of low quality forages, crop residues and wastes. Increased utilization of wastes as feed would reduce pollution and improve the environment. It might also lead to harmful residues in food and to inbalances in sheep feed that would require additional research.

E Total Potential Benefits

The gain in efficiency of the sheep industry of 7.5% from improved feed utilization from current Federal research would result in an increase in net returns to the farmer of about $.52 per ewe in 10 years or a decrease in the price of lamb meat of about 1¢ per pound if all of the benefit was passed on to consumers. The increase in annual net returns to farmers, middlemen and consumers would amount to about $4.9 million for the present ewe flock.

F Research Effort

1 Current Level

The current research effort on efficiency of feed use of 2.8 SY at Ithaca, Beltsville, Clay Center and Dubois is inadequate to achieve an appreciable proportion of the opportunity to improve the efficiency of the sheep industry. The 21.1 SY at State experiment stations helps makeup some of the deficiency by the total effort is still inadequate. The present small size of the industry may not justify more research but the opportunity for nutrition research to further increase efficiency and to stimulate the growth of the industry should be considered.

2 Expanded Level

An increase of ARS research of 5.2 SY (2.8 to 8) is recommended. About 82% of the additional research would be applied to important approaches that now receive no Federal attention. The remainder would be used to strengthen research already underway.

III.3 Improve Genetic Capacity for Production

A Current Technology

The national average of lambs produced per ewe was .98 in 1975. Averages for the various production areas vary from .87 in the Southeast to 1.16 in the Mideast. This trait has a high relationship to overall efficiency of production and has steadily increased since records have been kept but progress has been slow since the 1950's. Recently progress has been slowed by increasing losses to predators, particularly before docking in the Western States where the lamb crop

is first counted at docking time. For example, the lamb crop has only increased from .91 to .92 in the Intermountain area from 1969 to 1975 while the corresponding increase in the Southeast, where coyotes have hardly penetrated yet, was from .76 to .87. Mortality of sheep has decreased slightly in recent years but lamb mortality has sharply increased. The increases are attributed to coyotes as they destroy over twice as many lambs as sheep. However, losses to coyotes tend to mask technological improvements in reducing mortality.

Slaughter lambs averaged about 104 lb in weight in 1975 as compared with 95 lb in 1950. Days growth to slaughter is not know but it probably averages about 165 days. Days to slaughter has probably also decreased since 1950. Feed efficiency which can probably also be improved by breeding was described under III.2 in terms of feed costs of $25 per ewe.

Fleece weights averaged 8.3 lb in 1975 or only slightly above 8.0 in 1940 and 8.2 in 1950. The present average is even below the averages of 8.6 in 1960 and 8.4 in 1970. Fleece weights tend to decrease slightly as lamb production increases. Furthermore, breeds that excell in lamb production tend to have lighter fleeces at the same level of lamb production than breeds that excell in wool production. Thus, the increase in the economic value of slaughter lambs as compared to wool in recent years has led to shifts away from wool types and also to greater emphasis on increasing production of lambs for meat rather than wool.

Other traits that are difficult to measure directly but that can be improved by breeding include adaptability or environmental tolerance, milk production and the merit of the products, namely meat and wool.

B Visualized Technology

The current 2.7 SY on breeding techniques is expected to increase efficiency of sheep production by about 7% from 1975 to 1985. This will primarily be expressed by an increasing lambing rate from .98 to 1.05. Increases might be somewhat more rapid in the Eastern areas where lambing rates are higher now than in the Western areas. A slight reduction in mortality is expected but this may not be sufficient to affect the statistical measure. Calculation of estimated gains is shown in Table 3.

Weights of slaughter lambs will probably increase from 104 to about 114 lb. Days to slaughter will probably decrease slightly but this will not be measurable. Rate of gain will increase to about .55 lb per day. Feed efficiency is expected to improve by about .2% but this may not be measurable. Fleece weights may decline slightly as lamb production per ewe increases.

No measurable gains are expected in environmental tolerance, milk production and merit of meat and wool as practically no research is underway.

Improvements projected will largely come from choice of more productive breeds, use of the exotic Finnsheep breed, multibreed crossbreeding and selection. Research on improvement through breeding, particularly selection, has the advantage of producing annual gains while in other types of research the technology must be perfected before it can be applied.

C Research Approaches

1 Breed comparisons: Measure and compare important production and physiological traits of promising breeds for each ecosystem of sheep production (NCR, Clay Center, NE).

2 Exotic breeds: Import promising exotic breeds and compare with best domestic breeds both in pure breeding and crossbreeding for each ecosystem. Improve exotic breeds for performance under U.S. conditions (NCR, Clay Center, NE). Also see NRP 20460 Diagnosis and Control of Foreign Animal Diseases.

3 Crossbreeding: Compare breed combinations and different systems of crossbreeding for most efficient industry-wide production under each ecosystem (NCR, Clay Center, NE; WR, Dubois, ID).

4 Develop combined breeds: Combine 2 or more domestic or exotic breeds to develop synthetic breeds with improved productivity for each ecosystem. This would include development of paternal and maternal lines for specific systems of crossbreeding (NCR, Clay Center, NE).

5 Select for multiple lambs and early puberty: Increase the number of lambs marketed per ewe per year through selection for the ability to produce more lambs per birth and to lamb more often, up to twice yearly, at any time of the year. Selection for increased fertility in both sexes and for maximum reproduction after early puberty are included. Selection within each ecosystem will be necessary (WR, Duobis, ID).

6 Select for feed efficiency: Improve feed efficiency through selection for more efficient utilization of forages, crop residues and wastes within each ecosystem. Develop strains of sheep for utilization of specific low quality material such as animal wastes, garbage, sewage, sludge, abundant low quality forage, crop residues and abundant byproduct feeds (WR, Dubois, ID).

7 Select for growth rate: Improve rate of growth to heavier market weights through selection for growth rate within each ecosystem and within the important breeds for that ecosystem (NCR, Clay Center, NE; WR, Dubois, ID).

8 Select for low mortality: Select for improvement of viability of lambs both prenatal and postnatal, under vigorous environmental conditions within each ecosystem. Improve the genetic ability of sheep and lambs to resist internal parasites without therapeutic treatment. Select for natural resistance to specific diseases that are difficult to control such as foot rot, mastitis and pneumonia (NCR, Clay Center, NE). See NRP 20440 Control of Sheep and Other Animal Diseases.

9 Select for total production: Select, both on research centers and farms using indexes for combinations of important traits to give most efficient production. Include selection to increase yield of lean, size of loin eye and also to decrease the fat content particularly at heavy weights, also select for yield and quality of wool especially in ecosystems best suited for wool production. Also select for total production in exotic high fertility breeds that can be improved more rapidly than domestic breeds. Also select for increased life span both directly and through indicators that can be measured in a young animal (NCR, Clay Center, NE; WR, Dubois, ID).

10 Select for milk production: Select for improved milking ability to permit each ewe to raise more lambs to weaning age. Select for ewes with more functional teats up to 6 along with improved milking ability to increase the number of lambs that can be reared naturally. Where desirable develop strains of sheep to produce milk for cheese and other products (None).

11 Select for environmental tolerance: Select strains of sheep, within appropriate ecosystems, for natural tolerance to maximum temperature and humidity for high level reproduction and growth. This may include selection for woolless sheep where such may be more adaptable to specific environments. See NRP 20400 Livestock Structure and Equipment.

12 Select for meat merit: Improve flavor of sheep meat and reduce cooking odors by selection against the chemical components that produce undesirable flavors and odors. Select for sheep that have a reduced melting point of fat to make the fat more palatable (NCR, Clay Center, NE). See NPR 20600 Technologies for Marketing Livestock and Animal Products.

13 Genetic manipulation: Increase knowledge about sheep chromosomes and genetic indicators and develop cytological, chemical and other techniques to manipulate the germ plasm to obtain new methods for genetic improvement of sheep. Include the crossing and hybridization of domestic and wild strains of sheep and goats (None).

D Consequences of Visualized Technology

The increase in efficiency of sheep production from application of breeding techniques will increase net returns to farmers and at the same time reduce the cost of meat and wool to consumers. It is expected also that the supply of both lamb and wool will increase as a result of this increased efficiency and more of each should be available to provide food and fiber to a larger share of the world's population.

The efficiency of lamb production is now such that at least some farmers can persist with average farm prices that are about 39% of the comparable level of the index of consumers' prices for all goods and services in 1975 as compared to 100% in 1950. However, farm prices are still depressed by the reduced numbers due to predators. The depressing influence of surplus grain seemed to be removed in 1974. Farm prices for lambs are increasing now at any unusually high rate and may soon pass the point where higher returns will offset losses to coyotes. The increased efficiency since 1950 might permit an equitable return at about 60 to 70% of the comparable prices for all goods and services. A considerable part of the increased efficiency since 1950 probably resulted from breeding techniques. If this gain in efficiency can be maintained and increased, lamb meat should be available both for domestic use and export well below the cost of other goods and services and thus at a price the consumer would better be able to pay especially in developing countries.

E Total Potential Benefits

The gain in efficiency of the sheep industry of about 7% from genetic techniques would result in an increase in net returns to the farmer of about $.49 per ewe in 10 years or a decrease in the price of lamb meat of about 1¢ per pound if all of the benefit was passed on to consumers. The increase in annual net returns to farmers, middlemen and consumers would amount to about $4.6 million for the present ewe flock.

F Research Effort

1 Current Level

The current research effort on improvement of genetic capacity for production of 2.7 SY at Ithaca, Beltsville, Clay Center and Dubois is inadequate to achieve an appreciable proportion of the potential to improve the efficiency of the sheep industry as also is the 7 SY at State experiment stations. The total is about 1 SY per million ewes with a net return of about $7 million. An increased effort would seem warranted even with the present small size of the industry.

2 Expanded Level

An increase of ARS sheep genetic research of 7.3 SY (2.7 to 10) is recommended. About 27% of the recommended increase is for approaches that now receive no Federal attention. Another 54% of the recommended increase is for approaches that now have .1 or .2 SY. The expanded research program might be expected to triple the gain in efficiency in 10 years above the current research level.

III.4 Improve Management Practices and Systems

A Current Technology

Current technology in terms of productivity that also relates to management has been described under TO's 1, 2 and 3. Lambs born per ewe of .98 is particularly applicable to management practices and systems. Additional current technology for management may be described in terms of costs per ewe that total about $50 or about 88% of gross returns. The remaining returns (12%) is for management and capital. Labor costs of about $10 per ewe generally represent returns to family labor. Intensive and confinement production are practically nonexistent now and automatic feeding is very limited.

B Visualized Technology

A reduction in costs from $50 per ewe in 1975 to about $49.50 in 1985 is projected from the .3 SY currently available. The savings would come about through an increase in efficiency of intensive production and through increased marketing of ram lambs as intact males. In addition improved management practices often lead to additional increased lambs marketed per ewe and improved quality of the product but these have been included under other technologies. Savings in labor from these improvements would tend to shift returns from labor to management. Intensive and confinement production with automatic feeding will probably increase as better technology becomes available. Combined technologies may lead to greatest gains. Calculation of estimated gains is shown in Table 4.

C Research Approaches

1 Intensive production: Develop intensive production systems on forages for full, partial and intermittent use to utilize the total resources of an area more efficiently (NCR, Clay Center, NE).

2 Confinement production: Develop systems and facilities for confinement production on forages for full, partial and intermittent use to utilize available feed resources more efficiently and to reduce environmental losses (None).

3 Reduce labor costs: Develop labor saving methods and facilities for each aspect of sheep production (None).

4 Automatic feeding: Develop facilities and systems for practical automated forage feeding under different conditions (None).

5 Wool harvesting: Develop easier and less expensive ways of rémoving wool from sheep and lambs involving both practices and equipment. Adapt chemical shearing for use with large numbers by obtaining better chemicals and more precise control on wool removal and remaining wool cover. Develop better assay techniques for metabolites of wool removal chemicals and test for carcinogenesis and mutagenicity (None).

6 Market male lambs: Study the advantages and disadvantages of marketing male lambs as intact males to obtain the greater growth rate and higher lean content of the carcass. Develop management and nutritional practices to facilitate marketing of male lambs (NCR, Clay Center, NE).

7 Waste disposal: Develop practical methods of waste disposal (None).

8 Artificial rearing: Investigate more fully the nutrient requirements of young lambs and develop adequate but lower cost milk replacers. Reduce labor and equipment costs for artificial rearing (None). See NRP 20520 Technologies for Food and Feed Uses - Field Crops; NRP 20530 Technologies for Food and Feed Uses - Animal Products.

9 Environmental stress: Develop management procedures and equipment to reduce and prevent the harmful effects of stress due to heat, cold, humidity and other environmental factors (None).

10 Sheep behavior: Study natural behavior of sheep to facilitate breeding, reproductive, nutritive, and management methods of increasing efficiency of sheep production (None).

11 Combine technologies: Test the combinations of new technologies such as early weaning and rebreeding or breeding ewe lambs, pregnancy diagnosis and phenotypic selection for lamb production before market age of ewe lambs (None). See TO 1, Approach 11.

12 Simulation modeling: Develop and improve simulation modeling techniques to serve as a continuous guide to improve management practices under different conditions within each ecosystem (None).

D Consequences of Visualized Technology

The increase in efficiency of sheep production from improved management practices or systems will come about through reduction in costs and increases in lambs produced per ewe. Greater net returns to farmers should result as well as reduction in the cost of meat and wool to consumers.

E Total Potential Benefits

The gain in efficiency of sheep industry of about 1% from the .3 SY currently engaged in research to improve management practices and systems would increase net returns by about 7¢ per ewe in 10 years and an increase in annual net returns to farmers, middlemen and consumers of about $653 thousand for the present ewe flock.

F Research Effort

1 Current Level

The current research effort on improvement of management practices and systems for sheep production of .3 SY at Clay Center and 6 SY at State experiment stations is inadequate to achieve an appreciable proportion of the potential for improvement of efficiency from this TO. The total is about 2/3 per million ewes with a net return of about $7 million. An increased effort would seem warranted even with the current small size of the industry.

2 Expanded Level

An increase of ARS research of 6.7 SY (1.3 to 7) is recommended. About 79% of the recommended increase in for approaches that now receive no Federal attention and very little if any attention by State experiment stations. The expanded program might be expected to increase the gain in efficiency of the industry from 1% with the current program to 16.5%.

III.5 Improve Efficiency of Producing Quality Products

A Current Technology

The average live weight of lambs slaughtered in 1975 was 104 lb giving a dressed weight of 51 lb and a dressing yield of 49%. The average fat content of the lamb carcass is about 32%. The yield of boneless, trimmed, preferred cuts is about 44%. Lamb meat is generally of acceptable tenderness regardless of age or method of production.

Lamb meat may be criticized for being too high in fat, having fat with a high melting point, too small a loin eye area, and with cooking odors that are sometimes objectionable. Even though many prefer the lamb flavor, lamb would probably be more widely acceptable if the characteristic flavor was only slightly perceptible. An increase in the proportion of high-priced cuts would also be desirable.

Quality of the domestic wool clip approximate an average fiber diameter of 22 microns with a range of 16 to 40. The coefficient of variation averages about 23% with a range of 21 to 27%. Length of staple varies from 1.5 to 5.0 inches with a mean of about 2.5 inches. Crimps per inch varies from 8 to 30 per inch with an average of 16 per inch. Breaking strength of fiber bundles weigh about 13 kg with a range of 12.5 to 14.5 kg. Noilage averages about 10:1 with a range of 5:1 to 15:1. Wool with black fibers makes up about 3-5% of the clip while yellow wool makes up about 15% of the clip. Clean yield may vary from 25 to 70% with a mean of about 50%.

B Visualized Technology

The average live weight of lamb slaughtered is expected to increase from 104 lb in 1975 to 114 lb in 1985 but this gain is claimed under TO 3. Dressing percent is not expected to change from the 1975 value. No change is expected in the lean content of the carcass with the research input of .02 SY. A reduction in fat content from 32 to about 31% might be expected from the .29 SY working toward a more optimum fat content of the lamb carcass. New technology to identify and obtain optimum amounts of materials that produce a more desirable flavor in lamb is possible but probably no perceptible progress can be made from the .04 SY on desirability of lamb meat. An increase in efficiency of about 3% by 1985 is expected from research to increase the acceptability of heavy lambs with .25 SY available. Calculation of estimated gains is shown in Table 5.

No change is expected in wool quality as no funds are available for wool quality research. Some slight progress may result from TO 3 but the emphasis there is on the quality of wool produced.

C Research Approaches

1 Lean content: Increase the proportion of lean meat, loin eye area, and yield of more valuable cuts of lamb carcasses (NCR, Clay Center, NE).

2 Optimum fat: Decrease the proportion of internal and external fat in lamb carcasses while maintaining adequate intramuscular fat. Obtain an optimum subcutaneous fat covering over the lamb carcass (NCR, Clay Center, NE). See NRP 20530 Technologies for Food and Feed Uses-Animal Products.

3 Desirability of meat: Identify and obtain, probably through selection and/or feeding, optimum amounts of the materials that produce a desirable flavor of lamb. Identify and reduce the compounds that lead to undesirable cooking odors of lamb. Identify and change the compounds which affect the melting point of fat to obtain a more optimum level (NCR, Clay Center, NE). See NRP 20530 Technologies for Food and Feed Uses - Animal Products.

4 Heavy lambs: Increase the market weight of lambs to the extent necessary to obtain maximum efficiency of production without reducing palatability of the meat or quality of the carcass (NCR, Clay Center, NE). See NRP 20600 Technologies for Marketing Livestock and Animal Products.

5 Wool quality: Increase the yield of clean wool per sheep. Improve the quality and increase the yield per sheep of fine wool suited to the production of high quality apparel textiles. Increase the fiber length while maintaining uniformity of length to those lengths best suited to various manufacturing processes. Determine optimum crimps per inch for various manufacturing processes and to develop uniformly crimped wool. Increase the fiber strength of wool of various desired diameters and lengths for optimum use in the manufacture of textile products. Reduce and prevent the incidence of black fibers in white wooled sheep. Improve the handle or softness of wool for optimum use in production of high quality textile materials. Improve and reduce the cost of methods of measuring wool by producers. Develop methods for increasing the uniformity of fiber diameter to facilitate manufacturing processes and quality of textile products (None). See NRP 20550 Technologies for Fiber Uses.

D Consequences of Visualized Technology

The consequences of technology for improving the quality of sheep meat and wool will include an increase in the desirability and value of the products to the consumer. The relative cost of the products may be reduced on the one hand while the willingness of the consumer to pay a higher price is enhanced on the other. Improved quality should lead to greater demand for and consumption of lamb meat and wool.

E Total Potential Benefits

The sheep industry is expected to increase in efficiency by about 7% in 10 years from research to improve the quality of the products from the .6 SY now available. Gains will come about through reduced fat content and heavier slaughter lambs. The increased net returns to farmers would total about $.49 per ewe or about $4.5 million to farmers, middlemen and consumers with the present ewe flock.

F Research Effort

1 Current Level

The current research effort to improve the quality of sheep meat of .6 SY at Clay Center and 2.3 SY at State experiment stations is inadequate to achieve an appreciable proportion of the potential for improvement of efficiency from this TO. An increased effort would seem warranted even with the present small size of the industry.

2 Expanded Level

An increase of ARS research of 4.4 SY (.6 to 5) would permit expanded effort on each approach to improve meat quality. An increase of 1 SY on wool quality where very little work is underway now in SAES would increase the value of domestic wool to both the wool processor and the consumer.

III.6 Decrease Losses from Diseases, Pests and Other Hazards Through Production Practices

A Current Technology

Mortality from all causes is reported annually by SRS for each of lambs and sheep. The lamb crop is reported as lambs alive at docking in the 11 Western States, South Dakota and Texas. In the other States the lamb crop includes all lambs alive at birth. Lamb mortality is measured as a percent of the lamb crop and adult sheep mortality is measured as a percent of the January 1 sheep inventory.

Mortality of sheep was 7.78% in 1975. Deaths of sheep were 8.58% in 1950, 7.41% in 1960 and 8.02% in 1970. Sheep deaths have remained somewhat stable over the years except for increases in the late 40's and the late 60's. Predator losses (largely from coyotes) as measured by the increasing excess of lamb losses over sheep losses have increased since about 1954 for the entire U.S. but this increase has apparently been offset by new technology to reduce losses of sheep. This technology is probably largely in sheep management.

Lamb mortality was 13.83% or at the highest level for records back to 1940. The increase since 1954 has been attributed largely to predator losses as the excess of lamb losses over sheep losses has steadily increased since 1954 to a level about 6 times higher in 1975. The fact that coyotes kill more lambs than sheep is well established. Some advances in technology to reduce lamb mortality have probably been made in recent years but if so these have been offset by the increasing predator losses.

Coyotes are the major cause of sheep and lamb losses in the Western U.S. (Magleby, ERS-616, 1975). In the 15 Western States surveyed by ERS over half of the lambs lost to all causes were lost before docking and about 12% of those docked were lost from all causes. Predators killed about 8.1% after docking and over 2.5% of lambs born were killed by coyotes before docking. About 10.4% of stock sheep were lost to all causes with about 2.5% being lost to predators.

A trend in losses to coyotes is revealed by SRS data because coyotes kill over three times as many lambs as sheep. Thus, the upward trend of lamb losses as compared to sheep losses gives an indication of an upward trend in losses to coyotes and probably an upward trend in the coyote population. The correlation between differences between lamb and sheep losses in the 11

Western States with the independent upward trend of the percent of predator losses of all losses on the National Forests of Regions I to VI was .93. This indicates high accuracy of both measures although both are underestimates as they do not include predator losses before docking and the SRS data may not reveal losses to predators other than coyotes. Total coyote losses from SRS data for 1974 assuming there were no predator losses in 1972 would be about 5.9% of lambs as compared to the 6.2% estimated by ERS for the Western States.

Coyote losses appear to be the predominate cause of the decline of the sheep industry since the mid 60's resulting in a loss of sheep farms in the range of 4 to 8% per year. Farms lost tended to be below average in number of sheep per farm until 1973. Since 1973 the farms lost had above average numbers of sheep per farm (Table 1). Lamb losses in 1975, the most recent year studied, were the highest since 1940 and probably indicate that the coyote population is higher than for any previous year. The sheep industry is now declining at an alarming rate in spite of probable increasing net returns.

B Visualized Technology

Sheep mortality is expected to be about the same in 1985 as in 1975 at an average of about 8%. Increased losses to predators are expected because the coyote population shows little signs yet of leveling off. It will probably increase considerably because of the large territory not yet occupied and the obvious spread of the coyote Eastward and Southward. The increase in sheep losses from coyotes may be avoided, however, from management technology already available. New repellents, attractants and effective ways of reducing the coyote reproductive rate may reduce predator losses more than is expected. Calculation of estimated gains is shown in Table 6.

Lamb mortality is expected to continue to increase but probably at a slower rate as the coyote moves into areas where the farmer can better protect lambs with technology already available. Lamb mortality of about 16% is expected in 1985. Research to reduce coyote losses by reducing the coyote population will probably not be effective before 1985 as technology will need to be perfected and proven before it can be put in practice. Research on other technology to protect lambs from predators will probably only prevent a more rapid increase of predator losses.

C Research Approaches

1 Predator repellents: Find, develop and test materials which will repel predators or cause aversion when applied to sheep or sheep facilities (WR, Berkeley, CA and Dubois, ID).

2 Predator attractants: Find, develop and test materials which will attract predators either to take bait, food or to move to a particular spot (WR, Berkeley, CA).

3 Predator anti-fertility: Develop materials and methods to reduce the reproductive rate or to prevent reproduction in both sexes of coyotes and other predators (WR, Dubois, ID).

4 Predator reduction: Develop materials which will selectively kill predators humanely and quickly without significant damage to other wildlife, people or the environment. Find parasites and diseases specific to canids from which dogs can be protected to use as a biological means of controlling coyotes. Develop genetic methods for weakening coyotes and other predators to reduce their ability to survive and to kill farm livestock. Find drugs and other chemicals that will reduce the ability of coyotes and other predators to survive and to kill farm livestock (None). See NRP 20440 Control of Sheep and Other Animal Diseases.

5 Management to reduce predator losses: Develop and improve sheep management practices to reduce and prevent predator losses. Find suitable breeds of dogs and develop and adapt training techniques and methods to facilitate the use of dogs in killing and repelling predators to protect farm livestock and farmsteads. Develop fences and other devices to separate coyotes, dogs and other predators from sheep and other livestock (None).

6 Control internal parasites: Develop and improve management methods to reduce and prevent damage from internal parasites. See NRP 20440 Control of Sheep and Other Animal Diseases (None).

7 Control external parasites: Develop and improve management methods to reduce and prevent damage from external parasites (WR, Dubois, ID). See NRP 20480 Control of Insects Affecting Livestock.

8 Control metabolic disorders: Develop and improve management methods to reduce and prevent bloat and other metabolic disorders of sheep (WR, Dubois, ID). See NRP 20440 Control of Sheep and Other Animal Diseases.

9 Reduce losses from poisonous plants: Develop and improve management methods to prevent and reduce losses from poisonous plants (None). See NRP 20440 Control of Sheep and Other Animal Diseases.

10 Control diseases: Develop management method to reduce and prevent losses from various diseases including epididymitis, abortion, mastitis, lamb scours, pneumonia, caseous lymphadenitis, and foot rot (WR, Dubois, ID). See NRP 20440 Control of Sheep and Other Animal Diseases.

D Consequences of Visualized Technology

The consequences of visualized technology will likely be slight because with research underway it is probably not possible to halt the spread of the coyote over more territory nor to materially reduce coyote populations. Still coyote populations and territory will probably have to be reduced if a sheep industry is to be retained and if the livestock industry is to continue at its present level. This

probably cannot happen until the Government policy on predator control is changed to one of attempting to reduce the coyote population and to a policy that makes full but careful use of toxins to reduce the coyote population. Any reduction of the coyote population will be of benefit to other wildlife, game animals and birds and to endangered species. Better control of coyotes will also reduce losses of cattle, poultry and pigs.

Continued gains in reduction of losses from parasites metabolic disorders, poisonous plants and diseases will offset some of the increasing loss of predators and should reduce mortality in areas where the coyote has not yet invaded. These gains will increase the supply of meat at lower costs to the consumer. They also will help make more meat available to food deficit countries.

E Total Potential Benefits

The gain of efficiency of the sheep industry from reduction in mortality from diseases, pests and other hazards through management techniques of about 2% by 1985 would result in an increase in net returns to the farmer of about 14¢ per ewe or a decrease in the price of lamb meat of about .3¢ per pound. The increase in annual net returns to farmers, middlemen and consumers would amount to about $1.3 million.

F Research Effort

1 Current Level

The current research effort on reduction of mortality from diseases, pests and other hazards of 4 SY at Dubois, Idaho and cooperating stations is inadequate to achieve even a small proportion of the potential to improve the efficiency of the sheep industry. Predator control research is so difficult and expensive that even though essential, low returns are expected. Input from State experiment stations is included under NRP's 20440, 20470 and 20480 and the proportion devoted to management research or to predator research is not known.

2 Expanded Level

An increase of ARS research of 12 SY (4 to 16) is recommended. This increase in quite modest in relation to the problem, especially of predator control. About 33% of the recommended increase is for approaches for predator control that now receive almost no attention. Another 48% of the recommended increase is for approaches that now receive less than .2 SY. The expanded research program might be expected to increase efficiency by 4.5 times the expected gain from current research.

Goats

A Current Technology

There were an estimated 396 million goats in the world in 1972 with an annual increase of less than 0.5 percent per year. Goats in the United States total about 2.5 million with about 1.0 million kept for mohair production and about 1.5 million kept for milk and meat production. Goats are kept on about 21 thousand farms with 12 thousand farms having meat or "other" goats, 5 thousand farms with Angora goats and 4 thousand farms with milk goats. Over half of the goat farms are found in the South, followed by the North Central region with about a fourth, the West with a fifth and with the fewest in the Northeast. Goat production tends to increase in periods of depression and food shortage and they tend to be more common in developing countries than in developed countries.

Goats produce milk with high efficiency and tend to be important where people produce their own food. About 95% of the animals are kept in herds of less than 10 animals and are used primarily for milk for family use. Goats milk is often produced near large cities for use by people who are allergic to cows milk and especially for infants and invalids. The average dairy goat produces almost 500 kg. milk per year.

The Dairy Herd Improvement Program has a total of 28,095 records on dairy goats. Approximately 60% or 17,000 of these have sire and breed identification and would appear to be usable in a genetic evaluation. About 5-7,000 lactation records are being received annually on dairy goats. This represents a very significant percentage of the population. Thus, some emphasis on genetic evaluation and other programs in the dairy herd improvement program should offer a high probability of incorporating new technology to obtain the benefits from research.

Goats for mohair production are largely kept in Texas to convert low cost range forage to a highly valuable animal fiber. Goats are also grazed along with cattle and sheep to provide for better utilization of brushy pastures. The average clip of mohair per goat, including kids clipped in the fall was 7.1 pounds in 1974. Mohair becomes coarser with age and fine kid mohair is most valuable. Mohair goats were valued at $19 per head, January 1, 1976, as compared with $13 in 1975. Mohair prices averaged $1.37 per pound in 1974. Goat and mohair production give good returns but predator losses tend to prevent increased production.

Goats for meat are a small enterprise and few statistics are available. However, the meat is highly acceptable to many people over the world and offers a real opportunity for export. Furthermore, goats may produce meat more efficiently than other ruminants from the lowest quality feedstuffs.

B Visualized Technology

Milk goats are quite useful on small farms and could be increased rapidly in productivity through research. Incréased reproductive rates, decreased mortality, higher milk production and improved meat production as a byproduct could be achieved through research.

Research to increase the reproductive rate so that most of the mohair could be produced from kids where it is of maximum quality and so that the animals could be slaughtered for meat following the production of one kid and one or two mohair clippings would greatly increase the efficiency of the industry. Reduction of mortality from storms and chilling is important. More effective predator control is probably essential to the retention of a mohair goat industry.

Research needs for meat goats are much the same as sheep. An increase in number of offspring per mother per year along with more rapid growth rates would increase efficiency of production. Goats may produce meat as efficiently or more so than other ruminants now.

C Research Approaches

Technology for goat production has generally been derived from research with other animals. Although it is adequate for efficient production in comparison with other farm livestock there is opportunity for new technology, particularly in breeding and genetics, to give large increases in efficiency. Research approaches are as follows:

Increase the number of offspring per doe per year of dairy, meat and mohair goats through physiological methods including improvement of fertility, artificial insemination, reduction of mortality and control of sex (None).

Determine nutritive requirements, improve feed use, adapt use of feed additives and supplements, and find low cost feedstuffs for milk, meat and mohair production (None).

Improve and compare breeds, import and test exotic breeds, compare crossbreeding methods and select for important traits such as reproductive rate, efficiency of feed use and production of milk, meat and mohair (None).

Develop new management technology for confinement rearing, automatic feeding, waste disposal, reduction of labor costs, and alleviation of environmental stress. Combine an increase in the reproductive rate with the practice of delaying the slaughter of animals for meat until after the finer kid mohair is harvested and until after replacement offspring are produced (None).

Improve the quality of goat milk, cheese, meat and mohair to increase the usefulness of the products and demand for them. Delay the age at which the coarser, less valuable mohair is produced. Improve the palatability of meat from older animals (None).

Develop adequate methods for protection from predators. Develop management methods for reducing losses from internal and external parasites, diseases including abortion and mastitis, and from metabolic disorders. See NRP 20440 Control of Sheep and Other Animal Diseases (None).

D Consequences of Visualized Technology

Goats offer an opportunity to produce relatively new products for the American consumer and also for export. Goat and sheep cheese are highly valuable and are probably already being produced to the maximum in the areas where they are traditionally produced. Still world demand is increasing. Goats also use forage and brush that may be going unused now. Goats are well adapted to small farms and might be raised in all parts of the U.S. if there was a ready market for their products. Goat meat could probably be produced more cheaply than other meats and might find a more ready market now than even a year or so ago. Goats as well as sheep would require better predator control than is now practiced.

E Potential Benefits

The country would benefit from expanded goat production and more efficient goat production in the availability of an increased supply of high quality milk, fiber and meat at lower cost. If milk production per doe was increased from 455 to 910 liters, the increased value of milk per doe would be over $225 and a net benefit of over $3.4 million would accure to producers and consumers.

F Research Effort

Research on goats is practically nonexistent now except as experimental animals for basic research. Added research on goats should be done at the same locations as for sheep and possibly as for dairy cattle or beef cattle research. At least one lead scientist should spend full time on each of milk, mohair and meat goats. Additional research effort should come from those of various disciplines working with other animals such as sheep or cattle. A total of 2 to 3 SY on each type of goat would seem sufficient. Thus a total of about 7 SY on goats would seem adequate.

Horizes

A Current Technology

Horses for recreation, sport and work are attractive to a great many American people. Growth and development of a strong light horse industry has great promise as a means of improving income opportunities in rural areas and communities and by affording more citizens with recreational opportunities. Horse numbers probably exceed 7 million. Probably over 100 million people enjoy horses in one way or another or use them in their occupation.

B Visualized Technology

The increasing cost of feed, labor and facilities emphasizes the need for greater efficiency in the production and maintenance of horses. In addition horses could be developed for special purposes to make them more useful and to improve safety in their use. Breeding research to develop horses for work situations that may be most practical when supplies of petroleum become unavailable may be advisable. Small reservoirs of work horses for different applications might be desirable.

C Research Approaches

Increase fertility, in both sexes, reduce foal mortality and increase effectiveness of artificial insemination (None).

Determine nutrient requirements so that improved diets can be developed to save feed costs. Find lower cost feeds and increase the efficiency of feed use. Develop information on the effect of pelleting and feed processing on feed efficiency (None).

Determine the heritability of important traits such as speed, endurance, disposition, soundness, and susceptibility to lameness and disease. See NRP 20440 Control of Sheep and Other Animal Diseases (None).

Develop management practices to reduce labor costs, to improve speed, endurance, disposition and soundness. Determine effects of environmental stress and develop methods to reduce unfavorable effects. Reduce disorders such as colic, impaction, azotemia, anemia, heaves, osteomalacia, founder, rickets and possibly periodic opthalmia (None). See NRP 20440 Control of Sheep and Other Animal Diseases.

Improve safety of using horses, determine factors affecting disposition, develop strains of horses more suitable for special uses. Improve ease of handling, attractive appearance, dependability, obedience and responsiveness. Reduce undesirable traits such as kicks, bites, falls,

crushes, runaways and stable vices. Reduce lameness and other unsoundnesses such as blindness, sweeny, hernia, roaring, difficult breathing and leg and feet abnormalities (None).

Improve management practices to reduce losses from diseases, internal and external parasites, poisonous plants and metabolic disorders (None). See NRP 20440 Control of Sheep and Other Animal Diseases.

D Consequences of Visualized Technology

Horse production research should lead to more efficient horse production and increased usefulness of horses.

E Potential Benefits

Horses would be more useful to more people if they could be raised and kept more efficiently. Increasing cost of grain and feed will probably make the enjoyment of horses more of a luxury. Horses have been a part of the lives of people for centuries and they will probably continue to be. They may even again be used to a limited extent for transportation and power as energy becomes more scarce and expensive.

F Research Effort

Research to bring recreation with horses within the reach of more people by reducing the cost of production and maintenance would be worthwhile. There is practically no research on horse production now except for diseases (See NRP 20440 Control of Sheep and Other Animal Diseases). A limited amount of horse production research along with the disease research to the extent of about 2 SY would seem justified.

Rabbits

A Current Technology

Domestic rabbit production has declined considerably over the last 25 years because meat from other sources, particularly beef, pork and poultry fed surplus grains, was available at relatively low prices. However, rabbit meat production can be expected to increase in depression periods and in times of food shortages because rabbits can be produced under backyard conditions at least partly on low cost feeds. They offer both an opportunity for people to produce more of their own food and as a source of supplementary income if market outlets are available.

The domestic rabbit compares favorably with other meat producing animals and poultry in its conversion of feed crops into meat for human consumption. It lends itself as a source of supplemental income as the care of rabbits may be organized within either a 5-day week or a part-time schedule and the work is not arduous. Rabbits can easily be raised in suburban areas. They were particularly suited to areas of rural poverty because of their production of high quality protein at low cost. For this same reason they might be particularly useful in developing countries. There may be possibilities for this infant industry to develop into a major food industry.

The total commercial processing of rabbits for meat is estimated at about 1 million fryers annually. In addition there are from 50 to 100 thousand hobby producers and fanciers who produce another 4 to 8 million fryers.

Rabbit production is important in the support of medical research and other basic life science research. Animal numbers are below potential demands for medical research and teaching. The demand for biological materials from rabbits appears to be continually expanding.

B Visualized Technology

Research could probably lead to production of 5 litters per year of 8 young raised in each litter. Fertility should approach 98%. Artificial insemination and improved mating practices should save labor and increase progress from breeding. Feed costs might be reduced by 20%. Growth rate might also be increased by 20%. Much of these gains would be accomplished through breeding, particularly reproductive rate, feed efficiency, growth rate, adaptability to environmental stress and quality of products. Improved management practices and reduced labor and facility costs might increase net returns by 10%. Improved products and decreased mortality would be highly important in increased net returns.

C Research Approaches

Improve reproductive efficiency through elimination of the fall breeding depression, increasing fertility, increasing number of litters per year, and improving artificial insemination and mating practices (None).

Increase the efficiency of utilization of low cost feeds, improve digestibility and feed utilization through nutritional, biochemical and physiological studies, determine nutritive requirements more precisely, find lower cost but adequate feedstuffs and improve feeding practices (None).

Improve efficiency of rabbit production through more effective selection and breeding practices through testing of exotic breeds, comparisons of various crossbreeding combinations, develop more effective selection practices, and improve reproductive rate, feed efficiency, growth rate, adaptation to environmental stress, and quality of products through selection (None).

Develop production practices, facilities and equipment to reduce labor costs and to provide automatic and semi-automatic equipment for various levels of production. Determine effects of light, temperature and humidity on rabbit production and develop management practices to alleviate environmental stresses. Develop housing and other facilities to provide optimum production with minimum cost (None).

Improve the quality of rabbit meat, fiber, pelts and of biological materials produced. Increase weight and size of rabbit carcasses, obtain optimum proportion of fat and lean, and improve meat flavor (None).

Develop production practices to prevent and control important disease, parasite and metabolic disorder problems (None).

D Consequences of Visualized Technology

Rabbits, with current technology, can probably produce meat at lower or competitive costs than from other alternative meat sources in all parts of the world. Further research in control of diseases and parasites, genetic improvement of feed efficiency and meat quality and alleviation of environmental stresses and removal of seasonal periods of low fertility would lead to further increases in production efficiency from which consumers would benefit.

E Potential Benefits

The principal benefits would be the expansion of rabbit production and the resulting increased supply of meat and other products at less cost. The added advantage of making this source of income and food available to people who need it most would be quite worthwhile.

F Research Effort

There is practically no research on rabbits now except as experimental animals for basic research. Some intermittent disease research is done (See NRP 20440 Control of Sheep and Other Animal Diseases). A research effort of 3 SY of different disciplines but working across all technological objectives could be well justified.

Mink

A Current Technology

Mink are produced on over 1100 ranches, generally in the Northern States. The number of ranches decreased by 8% from 1973 to 1974. Mink females bred to produce kits in 1975 totaled 870,000, down 4% from the 905,000 the previous year. Mink pelt production in the United States in 1974 totaled 3,128,000 pelts or 3% above 1973. The leading States in mink production are Wisconsin, Minnesota and Utah.

By color class the percent of the total 1974 production was: pastel 31.7%, standard 28.1%, pearl 10.8%, demi buff, 9.8%, and violet 8.6%. Sapphire, white, gunmetal, pink, lavender hope, platinum, and pale brown accounted for the remaining 11%.

The mink industry largely utilizes byproducts and wastes from the livestock and poultry industries. The industry is very efficient but competition from foreign countries where labor and feed costs are lower and competition from pets for the available feed supply keeps the margin of returns at a very low level. Only the most efficient producers are able to stay in business.

B Visualized Technology

Efficiency of mink production could be markedly increased by improving the reproductive rate, rate of growth, reduced feed requirements, reduced mortality, reduced labor and facility costs and by further improvement in pelt and fur quality. Genetic improvement has been very successful in regard to color patterns but very little has been done toward genetic improvement of production efficiency and large opportunities exist.

C Research Approaches

Develop technology to improve fertility, increase number of of kits per whelping, increase whelpings per year, develop successful artificial insemination techniques and transfer of fertilized ova and bring about control of sex (None).

Increase efficiency of feed use, find cheaper feedstuffs, determine feed requirements more precisely and improve the use of dry diets (None).

Improve reproductive capacity, feed efficiency, rate of growth, pelt quality and adaptability to domestic conditions through selection and breeding (None).

Improve labor saving management practices, develop more automatic feeding equipment, improve reaction to environmental conditions particularly light and temperature and study mating, feeding and mothering ability to develop more efficient management practices (None).

Improve density of fur, pelt quality through fiber length, texture, type and distribution and through uniformity and desirability of various colors. Reduce incidence undesirable pelts (None).

Improve management practices to reduce incidence of various diseases (None). See NRP 2440 Control of Sheep and Other Animal Diseases.

D Consequences of Visualized Technology

The mink industry has been declining because of the cost-price squeeze largely as a result of foreign competition in fur pelts and domestic competition from food for pets. Unfortunately, the value of the raw product the farmer sells has little to do with the value of of the consumer product. In the case of mink the product is considered a luxury and therefore is quite vulnerable to the general economy but also to style changes. Technology to reduce the cost of production will probably be most helpful in keeping a mink industry.

E Potential Benefit

Research to reduce the cost of mink production and to increase efficiency of the mink would probably lead to retention and even expansion of the industry. The industry uses byproduct feedstuffs which are generally not acceptable for human or other animal consumption. The supply of such feedstuffs may increase with increasing condemnation of foods with residues of presumably harmful materials.

F Research Effort

Practically no research effort is now devoted to mink production although ARS is providing about .1 SY and very useful facilities to the SAES effort. The addition of 2 SY on mink research seems justified.

Production of Other Fur Animals

Various fur animals such as fox, nutria, beaver, marten, chinchilla and possibly others offer opportunities for producing a quality of fur products on low cost, byproduct feeds. Research needed is much the same as that for mink (None).

Production of Laboratory Animals

A large number of laboratory animals are used annually such as rodents, rabbits, primates, birds, marine animals, dogs, cats, frogs, insects and other animals. Research to increase efficiency of production of these animals and to improve their quality and usefulness for research would be helpful (None).

Production of Pets

About 45 million dogs and 25 million cats and a variety of other animals are kept as pets. These consume foodstuff that can sometimes be used for food for humans as well as economic animals. Research to obtain more efficient feed utilization by pets as well as breeding methods to improve satisfaction to their owners, to provide more acceptable fertility control, and to develop more efficient production methods would reduce their cost and increase their usefulness to the consumer (None).

Production of Domestic Fish

Domestic fish production results in additional varieties of food to replace shrinking supplies of ocean fish. Production problems are much the same as in the other farm livestock. Research is needed to increase genetic capacity for year around production, for increased growth rates, fecundity, disease resistance, tolerance to varying water quality and environmental conditions, increased efficiency of feed conversion, increased reproductive rates, improved production, management and cultural methods and improved quality and flavor of fish products (None).

Production of Exotic Game Animals

Exotic game animals are increasing in popularity on Texas ranches where hunting for sport and food is an important agricultural enterprise. Research to increase the variety of game animals, particularly those that are resistant to predators and to produce them in predator free areas to ages when they are less vulnerable to predators and research to improve the efficiency of production of such animals would increase their value and reduce costs to consumers (None).

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Concur	T. B. Kinney Assistant Administrator	10/22/76 Date
Concur	E. L. Corley Director PACS	11-6-76 Date
Approval	Ralph J. McCracken Associate Administrator	11/8/76 Date

NOTE: The expanded support level reflected in this National Research Program represents staffs views as to the additional level of staffing that can be effectively used in meeting the long-term visualized objectives for this program. These do not reflect commitments on the part of the Agency.

Appendix I

Calculation of Gains in Efficiency of Sheep Production from Research

Current costs and returns have been approximated on a per breeding ewe basis from Hall, ESC-576, 1973; Goodsell, AER-195, 1971 and from recent SRS reports:

Returns:	Lamb 105 lbs. X $ .45	$47
	Wool X $ .72	6
	Culls .2 X 140 X $ .10	3
	Manure and other (arbitrary estimate)	1
	Subtotal	57
Costs:	Feed	$25
	Replacements	6
	Labor	10
	Land and facilities	4
	Other costs	5
	Subtotal	$50
	Net returns for investment and management	$ 7

The main components of increased efficiency of sheep meat production will be increased numbers of lambs per ewe per year, decreased mortality, increased growth rates and feed efficiency, and decreased production costs. Expected gains will be estimated for each of these based largely on extremes that have already occurred. Some estimates are objective and some are quite arbitrary where objective estimates are not feasible. Maximum expected ultimate gains will be used as ceilings for total estimated gains from research to avoid double counting.

Ewes have produced up to 9 lambs per birth but at least two litters of 6 normal lambs have been produced in the U.S. without any special treatment. Thus 6 lambs is reasonable as the maximum for litter size. Also quite a number of ewes in different locations have lambed twice in one year (once every 6 months) both with and without hormone treatments. Therefore, two lambings per year or a total of 12 lambs per ewe per year is reasonable as the maximum number of lambs per ewe per year. However, this ceiling has been arbitrarily reduced to 10 lambs per ewe per year in order to provide more conservative estimates and to follow the suggestion of Wilson (Chem. & Ind. 27:899-902, 1968).

Mortality rates of as low as 2% per year for lambs and 1% per year for all other sheep are possible but ceilings of 4% per year for lambs and 2% for all other sheep are proposed as conservative ceiling values. Growth rates of one pound per day (Wilson, 1968) has often been exceeded but may be a reasonable maximum for largely forage diets. Expected feed efficiency must be arbitrary but a maximum reduction of 50% of feed requirements is estimated as possible. A ceiling of 40% reduction in feed requirements is proposed as a conservative estimate. Changes in management, labor and facility costs are also difficult to estimate objectively but a ceiling of a 50% reduction through research seems possible. However, a ceiling of 40% reduction in costs is proposed. The ceiling of 10 years in life span was adopted from Wilson, 1968 although 12 years or more would be feasible.

Estimation of cost-benefits has been condensed in tabular form for each technological objective and approach. Current technology has been tabulated for each research approach in a simplifed way in the second (unnumbered) column of tables 1 to 6 to provide a beginning point for the estimation of potential benefits. The corresponding visualized technology for each research approach is then given in column 1. Visualized technology was deliberately calculated to be additive to each other approach in so far as possible. Then in column 2 the increased returns per year are calculated. For example, if the expected gain was .02 lamb per ewe then .02 is multiplied by the current net return of a ewe ($7) to obtain the increased return per ewe per year of $0.14. The increased cost per ewe per year to use the technology is calculated in column 3 in most cases as 50% of the returns from the visualized technology. This cost is based on the assumption that a new technology will probably not be accepted if it will not return at least double the cost. In cases where the technology obviously receives low if any increase in costs a cost of 10% is used. For example, once breeding stock for improvement of meat merit becomes available it should cost no more to produce such breeding stock than any other.

The difference between columns 2 and 3 is entered in column 4 as the increased net return in dollars from application of the technology and thus is an expression of the potential benefit. In column 5 the potential benefit is expressed in abstract terms by dividing the increase in monetary net returns by the estimated average current net return per ewe of $7.

Probably no one approach is applicable to all farms or to all parts of the United States. Therefore, a rough estimation is made to the nearest 10% of the expected implementation of the technology over the whole industry in column 6. Then by multiplying entries in column 5 by those in column 6 the net gain in efficiency for the entire industry from a particular approach is obtained with the assumption that the research

was successful enough to be applied and is entered in column 7. This column is probably the best projected estimate of potential benefits. Attempts were made to be quite conservative in these estimates (minimum) and of course more successful research would lead to greater implementation.

In column 8 the research effort in terms of scientist years to obtain maximum success was estimated. These estimates are necessarily very rough and uncertain but they are based on similarly rough estimates of research gains in the past in efficiency of sheep production. Very little if any documentation can be obtained for these estimates but a serious attempt was made to be consistent among the different approaches according to the difficulty of the research and the uncertainly of success.

The estimated gain in efficiency per SY in column 9 is obtained by dividing the entries in columns 7 by those in column 8 together. This estimate is the final cost-benefit value that should indicate the impact on the total efficiency of the industry expected from each scientific year expended. The values could be converted to dollars by using the total net return to the industry and the cost of a scientific year that would apply at any given time. They may be useful in determining the relative emphasis that might be given to each approach but in this plan more attention has been given to expected impact and the difficulty of obtaining it. Of course, approaches that should be applied within each ecosystem will require more scientific effort than those that can be developed at one location for the entire country.

Column 10 was obtained by multiplying the recommended number of Federal scientists by 10 (years) by the expected gain from 1 SY in column 9. Entries in column 11 was obtained in the same way but by using the current number of Federal scientists. Columns 12 and 13 contain the recommended and current number of Federal scientists respectively. Column 14 gives the number of State scientists (1973) but these can generally be given only for an entire TO.

Tables 1-6 follow.

Table 1. Research for Improvement of Reproductive Efficiency

Approach	Current Technology lamb/ewe	1/ Visualized Technology lamb/ewe	2/ Inc. ret. per ewe per yr.	3/ Inc. cost per ewe per yr.	4/ Inc. net ret.	5/ Inc. net ret. as part of $7	6/ Exp. Impl.	7/ Gain in effic.	8/ Tot. SY req.	9/ Gain per SY	10/ Gain in effic. in 10 yrs.	11/ Gain in effic. in 10 yrs. from cur. SYs	12/ Rec. Min. Fed. Sci.	Current SY's 13/ Fed.	Current SY's 14/ St.
1. Reduce infertile ewes	-.1	+.02	$ .14	$ .07	$ .07	.010	.5	.005	10	.0005	.001	.001	.2	.1	
2. Improve ram fertility	-.1	+.02	.14	.07	.07	.010	.6	.006	10	.0006	.001	.002	.2	.4	
3. Increase multiple lambs	1.0	+.50	3.50	1.75	1.75	.250	.4	.100	30	.0033	.033	.015	1.0	.45	
4. Increase lambing frequency	1.0	+1.00	7.00	3.50	3.50	.500	.4	.200	30	.0067	.134	.105	2.0	1.25	
5. Store ram semen and improve AI	-.2	+.15	1.05	.53	.52	.074	.4	.030	40	.0008	.008		1.0		
6. Detect estrus and ovulation	-.2	+.04	.28	.14	.14	.020	.4	.008	10	.0008	.002		.2		
7. Store and transplant embryos	1.0	+.05	.35	.18	.17	.024	.1	.002	20	.0001	.001	.000	.2	.05	
8. Reduce prenatal mortality	-.2	+.05	.35	.18	.17	.024	.6	.014	30	.0005	.001	.001	.2	.2	
9. Synchronize ovulation	1.0	+.20	1.40	.70	.70	.100	.5	.050	10	.0050	.050		1.0		
10. Control lambing time	1.0	+.50	3.50	1.75	1.75	.250	.8	.200	20	.0100	.200		2.0		
11. Diagnose pregnancy	1.0	+.10	.70	.35	.35	.050	.6	.030	20	.0015	.009	.002	.6	.1	
12. Increase mating of ewe lambs	1.0	+.02	.14	.07	.07	.010	.8	.008	20	.0004	.001	.000	.2	.05	
13. Environment and reproduction	1.0	+.05	.35	.18	.17	.024	.3	.007	20	.0004	.001	.001	.2	.2	
14. Control sex	.5♂, .5♀	.75♂, .25♀ .25♂, .75♀	.95	.48	.47	.094	.5	.047	20	.0024	.024		1.0		
Total								.707	290		.466	.127	10.0	2.8	18.2

Footnotes to Tables 1 - 6

1/ Anticipated total gains were apportioned among various appropriate approaches according to predicted results.

2/ Increased returns per ewe per year from each approach to improve efficiency.

3/ Increased cost per ewe per year to apply the improved technology.

4/ Increased net returns by subtracting 3 from 2.

5/ Increased net returns as a part of base net return of $7 per ewe.

6/ Expected implementation nationwide.

7/ Expected gain in efficiency as part of annual net returns (5 x 6).

8/ Estimated total SY required to complete research approach.

9/ Estimated gain per SY (7 ÷ 8).

10/ Expected gain in 10 years from recommended SY's (10 x Col. 12 x Col. 9).

11/ Expected gain in 10 years from current SY's (10 x Col. 13 x Col. 9).

12/ Recommended minimum Federal SY in order to make effective progress.

13/ Current Federal SY's.

14/ 1973 allocation.

Table 2. Research for Improvement of Feed Efficiency a/

Approach	Current Technology $ per ewe per year	1/ Visualized Technology $ per ewe per year	2/ Inc. ret. per ewe per yr.	3/ Inc. cost per ewe per yr.	4/ Inc. net ret.	5/ Inc. net ret. as part of $7	6/ Exp. Impl.	7/ Gain in effic.	8/ Tot. SY req.	9/ Gain per SY	10/ Gain in effic. in 10 yrs.	11/ Gain in effic. in 10 yrs. from cur. SYs	12/ Rec. Min. Fed. Sci.	Current SY's 13/ Fed.	Current SY's 14/ St.
1. Nutrient requirements	-25	+$1.25	$ 1.25	$ .63	$ .62	.089	.5	.045	20	.0022	.011	.004	.5	.2	
2. Feed supplements	-25	+.75	.75	.38	.37	.053	.6	.032	30	.0011	.011	.002	1.0	.2	
3. Feed additives	-25	+.50	.50	.25	.25	.036	.5	.018	20	.0009	.009		1.0		
4. Range nutrition	-25	+1.00	1.00	.50	.50	.071	.6	.043	20	.0022	.066		3.0		
5. Nutrition for reproduction	-25	+1.00	1.00	.50	.50	.071	.6	.043	20	.0022	.011	.020	.5	.9	
6. Low cost feedstuffs	-25	+.75	.75	.38	.37	.053	.8	.042	10	.0042	.042	.042	1.0	1.0	
7. Feed intake	-25	+.25	.25	.13	.12	.017	.2	.003	20	.0002	.000	.000	.1	.1	
8. Efficiency indicators	-25	+.25	.25	.13	.12	.017	.2	.003	30	.0001	.000		.1		
9. Nutrient recycling	-25	+.25	.25	.13	.12	.017	.2	.003	30	.0001	.000		.1		
10. Non-protein nitrogen	-25	+.50	.50	.25	.25	.036	.8	.029	10	.0029	.015	.006	.5	.2	
11. Body composition	+47	+.25	.25	.13	.12	.017	.2	.003	10	.0003	.001	.001	.1	.2	
12. Feed processing	-25	+.25	.25	.13	.12	.017	.2	.003	10	.0003	.001		.1		
Total								.267	230		.167	.075	8.0	2.8	21.1

a/ See Table 1 for footnotes.

Table 3. Research for Improvement of Genetic Capacity a/

Approach	Current Technology	1/ Visualized Technology	2/ Inc. ret. per ewe per yr.	3/ Inc. cost per ewe per yr.	4/ Inc. net ret.	5/ Inc. net ret. as part of $7	6/ Exp. Impl.	7/ Gain in effic.	8/ Tot. SY req.	9/ Gain per SY	10/ Gain in effic. in 10 yrs.	11/ Gain in effic. in 10 yrs. from cur. SYs	12/ Rec. Min. Fed. Sci.	Current SY's 13/ Fed.	Current SY's 14/ St.
			$	$	$										
1. Breed comparisons	1 lamb/ewe	+.1 lamb/ewe	.70	.35	.35	.050	.5	.025	20	.0012	.006	.001	.5	.1	
2. Exotic breeds	1 lamb/ewe	+.5 lamb/ewe	3.50	1.75	1.75	.250	.6	.150	30	.0050	.050	.005	1	.1	
3. Crossbreeding	1 lamb/ewe	+.2 lamb/ewe	1.40	.70	.70	.100	.6	.060	20	.0030	.030	.012	1	.4	
4. Development of combined breeds	1 lamb/ewe 80 lbs. lamb /ewe $6/ewe-wool	+.5 lamb/ewe +1 lb lamb/ ewe ($.45) +$.1/ewe/yr.	3.95	1.98	1.97	.282	.5	.141	60	.0024	.024	.007	1	.3	
5. Select for multiple lambs and early puberty	1 lamb/ewe	+1.5 lamb/ ewe	10.50	5.25	5.25	.750	.6	.450	240	.0019	.019	.013	1	.7	
6. Select for feed efficiency	-$25/ewe	+$3/ewe	3.00	1.50	1.50	.214	.7	.150	80	.0019	.019	.002	1	.1	
7. Select for growth rate	.4 lb/day for 180 days or 80 lbs	+18 lbs/ewe ($8.10)	8.10	4.05	4.05	.579	.6	.347	80	.0043	.043	.009	1	.2	
8. Select for low mortality	1 lamb/ewe 80 lbs lamb/ ewe	+.2 lambs/ ewe +1 lb lamb/ ewe ($.45)	1.85	.93	.92	.131	.6	.079	240	.0003	.002		.5		
9. Select for total production	1 lamb/ewe 80 lbs lamb/ ewe $6/ewe-wool	+1.5 lambs/ ewe +4 lbs/ewe ($1.80) $.6/ewe/year	12.90	6.45	6.45	.921	.7	.645	240	.0027	.027	.020	1	.75	

Table 3. Research for Improvement of Genetic Capacity a/ (Continued)

Approach	Current Technology	1/ Visualized Technology	2/ Inc. ret. per ewe per yr.	3/ Inc. cost per ewe per yr.	4/ Inc. net ret.	5/ Inc. net ret. as part of $7	6/ Exp. Impl.	7/ Gain in effic.	8/ Tot. SY req.	9/ Gain per SY	10/ Gain in effic. in 10 yrs.	11/ Gain in effic. in 10 yrs. from cur. SYs	12/ Rec. Min. Fed. Sci.	Current SY's 13/ Fed.	14/ St.
			$	$	$										
10. Select for milk production	1 lamb/ewe	+.75 lamb/ ewe	5.25	2.63	2.62	.374	.4	.150	120	.0012	.006		.5		
11. Select for environmental tolerance	1 lamb/ewe	+.5 lamb/ewe	3.50	1.75	1.75	.250	.2	.050	200	.0002	.001		.5		
12. Select for meat merit	$.45/live lb.	+5¢ per lb. ($4/ewe)	4.00	2.00	2.00	.286	.2	.057	240	.0002	.001	.000	.5	.05	
13. Genetic manipulation	1 lamb/ewe	+.5 lamb/ ewe	3.50	1.75	1.75	.250	.2	.050	240	.0002	.001		.5		
Total								2.354	1810		.229	.070	10	2.7	7

a/ See Table 1 for footnotes.

Table 4. Research to Improve Management Practices and Systems a/

Approach	Current Technology	1/ Visualized Technology	2/ Inc. ret. per ewe per yr.	3/ Inc. cost per ewe per yr.	4/ Inc. net ret.	5/ Inc. net ret. as part of $7	6/ Exp. Impl.	7/ Gain in effic.	8/ Tot. SY req.	9/ Gain per SY	10/ Gain in effic. in 10 yrs.	11/ Gain in effic. in 10 yrs. from cur. SYs	12/ Rec. Min. Fed. Sci.	Current SY's 13/ Fed.	Current SY's 14/ St.
			$	$	$										
1. Intensive production	-$50/ewe	+$1/ewe	1.00	.50	.50	.071	.3	.021	30	.0007	.007	.001	1	.2	
2. Confinement production	-$50/ewe	+$1/ewe	1.00	.50	.50	.071	.3	.021	20	.0011	.011		1		
3. Reduce labor costs	-$10/ewe	+$2/ewe	2.00	1.00	1.00	.143	.8	.114	30	.0038	.076		2		
4. Automatic feeding	-$5/ewe	+$.1/ewe	.10	.05	.05	.007	.1	.001	5	.0002	.001		.2		
5. Wool harvesting	-$1/ewe	+$.5/ewe	.50	.25	.25	.036	.3	.011	20	.0006	.003		.5		
6. Market male lambs	+$45/ewe	+$1.5/ewe	1.50	.75	.75	.107	.8	.086	10	.0086	.043	.009	.5	.1	
7. Waste disposal	-$1/ewe	+$.1/ewe	.10	.05	.05	.007	.1	.001	5	.0002	.001		.2		
8. Artificial rearing	1 lamb/ewe	+.1 lamb/ ewe	.70	.35	.35	.050	.6	.030	10	.0030	.012		.4		
9. Environmental stress	1 lamb/ewe	+.15 lamb/ ewe	1.05	.53	.52	.074	.3	.022	50	.0004	.002		.5		
10. Behavior	1 lamb/ewe	+.05 lamb/ ewe	.35	.18	.17	.024	.3	.007	20	.0004	.001		.2		
11. Combine technologies	1 lamb/ewe	+.1 lamb/ ewe	.70	.35	.35	.050	.6	.030	20	.0015	.004		.3		
12. Simulation modeling	1 lamb/ewe	+.1 lamb/ewe +$.05/ewe	.70 .05	.38	.37	.053	.4	.021	10	.0021	.004		.2		
Total								.365	230		.165	.01	7	.3	6

a/ See Table 1 for footnotes.

Table 5. Research to Improve Quality of Products a/

Approach	Current Technology	1/ Visualized Technology	2/ Inc. ret. per ewe per yr.	3/ Inc. cost per ewe per yr.	4/ Inc. net ret.	5/ Inc. net ret. as part of $7	6/ Exp. Impl.	7/ Gain in effic.	8/ Tot. SY req.	9/ Gain per SY	10/ Gain in effic. in 10 yrs.	11/ Gain in effic. in 10 yrs. from cur. SYs	12/ Rec. Min. Fed. Sci.	Current SY's 13/ Fed.	Current SY's 14/ St.
1. Lean content	+$47/ewe	+$2.25/ewe	$ 2.25	$ 1.13	$ 1.12	.16	.6	.096	30	.0032	.038	.001	1	.02	
2. Optimum fat	+$47/ewe	+$2.25/ewe	2.25	1.13	1.12	.16	.6	.096	30	.0032	.038	.009	1	.29	
3. Desirability of meat	+$47/ewe	+$2.25/ewe	2.25	1.13	1.12	.16	.6	.096	50	.0019	.019	.001	1	.04	
4. Heavy lambs	+$47/ewe	+$27/ewe	27	23	4.00	.571	.8	.457	20	.0228	.028	.057	1	.25	
Subtotal		+$33.75/ewe			7.36			.745	130		.123	.068	4	.6	2.3
5. Wool quality	+$6/ewe	+$1/ewe	1.00	.50	.50	.071	.4	.028	20	.0014	.014		1		
Total								.773	150		.137		5	.6	2.3

a/ See Table 1 for footnotes.

Table 6. Research to Reduce Losses from Diseases, Pests and Other Hazards Through Production Practices a/

Approach	Current Technology	1/ Visualized Technology	2/ Inc. ret. per ewe per yr.	3/ Inc. cost per ewe per yr.	4/ Inc. net ret.	5/ Inc. net ret. as part of $7	6/ Exp. Impl.	7/ Gain in effic.	8/ Tot. SY req.	9/ Gain per SY	10/ Gain in effic. in 10 yrs.	11/ Gain in effic. in 10 yrs. from cur. SYs	12/ Rec. Min. Fed. Sci.	Current SY's 13/ Fed.	Current SY's 14/ St.
			$	$	$										
1. Predator repellents	1 lamb/ewe	+.05 lamb/ewe	.35	.18	.17	.024	.8	.019	30	.0006	.012	.010	2.0	1.6	
2. Predator attractants	1 lamb/ewe	+.05 lamb/ewe	.35	.18	.17	.024	.8	.019	30	.0006	.012	.010	2.0	1.7	
3. Predator anti-fertility	1 lamb/ewe	+.05 lamb/ewe	.35	.18	.17	.024	.8	.019	40	.0005	.010	.002	2.0	.5	
4. Predator reduction	1 lamb/ewe	+.10 lamb/ewe	.70	.35	.35	.050	1.0	.050	40	.0012	.024		2.0		
5. Management to reduce predator losses	1 lamb/ewe	+.05 lamb/ewe	.35	.18	.17	.024	.6	.014	40	.0004	.008		2.0		
6. Control internal parasites	1 lamb/ewe	+.05 lamb/ewe	.35	.18	.17	.024	.8	.019	40	.0005	.010	.000	2.0	.02	
7. Control external parasites	1 lamb/ewe	+.005 lamb/ewe	.03	.02	.01	.001	.5	.001	10	.0001	.000		.1	.02	
8. Control metabolic disorders	1 lamb/ewe	+.015 lamb/ewe	.10	.05	.05	.007	.5	.003	20	.0002	.002		1.0	.02	
9. Reduce loss from poison plants	1 lamb/ewe	+.05 lamb/ewe	.35	.03	.32	.046	.6	.028	40	.0007				(2.0)b/	
10. Control diseases	1 lamb/ewe	+.08 lamb/ewe	.56	.06	.50	.071	.5	.036	40	.0009	.026	.001	2.9	.14	
Total								.208	330		.104	.023	16.0	4.0	

a/ See **Table 1** for footnotes.
b/ See NRP 20470 Toxicology and Metabolism of Agricultural Chemicals and Poisonous Plants. SY shown are an estimate of current effort but is not included in total for this NRP.

Appendix II

Explanation of Ecosystem, Sheep Production Areas

Sheep research may be adapted to a regional approach as sheep production is quite different in various parts of the United States. Closer cooperation between ARS and SAES and among States within areas may be facilitated by such an approach.

The country has been arbitrarily divided into 8 areas, each representing a different sheep ecosystem (Figure 1). Area boundaries follow regional and State lines rather than natural boundaries because administration of research also follows State and regional lines. Furthermore, statistics used to determine current technology and to monitor research progress are available by States. Sheep industry leaders have endorsed this concept of sheep production research and have taken part in designating area boundaries and centers in their development of a blueprint for the future of sheep in the U.S.

Sheep Ecosystem Production Areas and Established Centers

Ecosystem	States	Center
West Coast	Calif., Hawaii, Ore., Wash.,	To be determined
Intermountain	Ariz., Colo., Ida., Mont., Nev., N. Mex., Utah, Wyo.	Dubois, Idaho
Southwest	Texas	San Angelo, Texas
West North Central	Alaska, Ia., Kan., Minn., Mo., Neb., N. Dak., So. Dak.	Clay Center, Neb.
East North Central	Ill., Ind., Mich., Ohio, Wis.	Wooster, Ohio
Mideast	Ark., Ky., N. Car., Okla., Tenn., Va.	To be determined
Southeast	Ala., Fla., Ga., La., Miss., So. Car.	To be determined
Northeast	Conn., Del., Maine, Md., Mass., N.H., N.J., N.Y., Pa., R.I., Vt., W. Va.	Ithaca, N.Y.

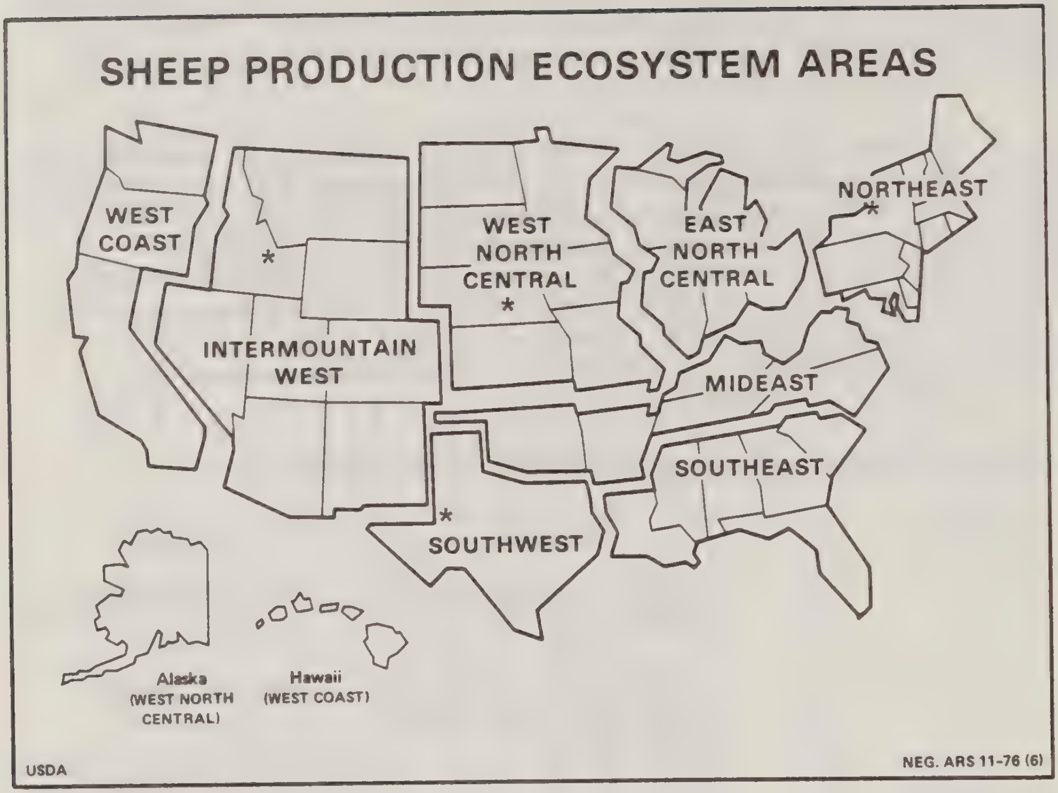

Figure 1. Boundaries of eight sheep production ecosystems of the United States.

* Area research center for sheep.

There is considerable overlapping of the different sheep ecosystems. Often there is no definite physical boundary but rather a gradual change between areas. However, administrative convenience is probably far more because of the arbitrary boundaries. Federal scientists can easily pass over State boundaries. Farmers will relate to the appropriate area and center regardless of where the boundary lines have been drawn. Centers of research within each sheep ecosystem have evolved in a traditional manner but a few are yet to be established. Final determination should be made by administrators and scientists within each area as to whether there is to be such a center and where it should be located. Changes can be made in area boundaries or center locations at any time if desirable. The research within each ecosystem should be fully cooperative and closely coordinated with State agricultural experiment stations, and with State and Federal administrators and scientists within the area and probably in certain cases with some outside of the area although this may be done quite informally. In some cases the center might be operated by a State. Other State or Federal stations within an ecosystem might serve as co-centers or satelites to the designated center.

The various sheep ecosystem production areas vary somewhat as conditions under which sheep are produced vary over the world. The West Coast and Mideast areas are somewhat similar to a part of New Zealand. The Southwest is similar to a part of Australia. The Intermountain area is something like Southern Europe. The West North Central area is somewhat like the Ukraine. The East North Central is somewhat like North Western Europe. The North Eastern area is similar in some respects to England and Ireland. The South East is somewhat subtropical.

The concept of research to develop sheep and methods for specific environments was developed in regional projects where scientists working together under widely varying conditions realized that breeds, individual sheep, and management, reproductive and nutritional techniques needed to be fitted to each set of environmental conditions (Southern Cooperative Series Bulletin No. 119, 1966; North Central Regional Research Publication 198, 1970; and Ohio Research Circular 179, 1970).

Progress in developing technology for efficiency of sheep production may be increased on a national basis by adapting both sheep and technology to specific environments. Maximum increases in efficiency will probably come from adaptation of technology to the requirements of each of the quite different ecosystems of sheep production which exist over the country. Much of the further increase in efficiency will come from increasing our genetic resources through sheep. This will involve breeding and selecting strains of sheep for both higher productivity and greater adaptation to the environment of each particular sheep ecosystem. Sheep are more affected by the natural environment than other farm livestock

except range cattle because they are generally kept in the open and because they live largely on natural forages. Nutrition, reproduction, management and products produced also vary with the environment and therefore technology for the future, needs to be developed by small multidisciplinary groups of scientist working within each sheep ecosystem.

The ecosystem production area concept is probably most important for improving sheep through breeding so that natural selection along with artificial selection will tend to bring about greater adaptability as well as greater productivity. The practice of bringing replacement ewes from the West to the East has been economical in the short run but it has led to only slow increases in productivity and practically no increase in adaptability. The farmer even without research would probably bring about improvements if he could make his selections for replacements from within the area where he is operating.

Appendix III

Statistics of Sheep Production

Statistics of sheep production have been assembled by area and for the entire United States to show the characteristics of the industry and available information on traits related to efficiency of production (Tables 7-15). Statistics are all taken from Statistical Reporting Service reports. These will be updated annually to show progress and to serve as a monitor of research gains. Additional background statistics will also be included as relevant.

Table 7. Sheep Production Statistics for the United States 1/

Year	All Sheep Inv. Jan. 1 1000	Ave. value per head end of year $	No. of sheep farms	Ave. no. sheep/ farm	Lambs per ewe	Sheep deaths of sheep inv. %	Lambs deaths of lamb crop %	Ratio no. of cattle to sheep begin. of year	Ratio value of cattle to sheep (end of year)	Ave. fl. wt. lbs.	Meat per ewe one year and older lbs.
1940	52,107	6.73			.870	7.50	9.02	1.31	6.42	8.0	25.0
1	53,920	8.60			.895	7.77	9.74	1.33	6.40	8.1	26.1
2	56,213	9.66			.865	7.17	9.14	1.35	7.17	7.9	27.9
3	55,150	8.71			.829	7.89	10.69	1.47	7.85	7.9	27.2
4	50,782	8.57			.843	8.06	10.32	1.68	7.81	7.8	27.9
5	46,520	9.69			.865	7.35	9.21	1.84	7.86	8.0	30.2
6	42,362	12.60			.887	7.38	9.32	1.94	7.74	8.1	31.8
7	37,498	15.40			.882	7.59	9.50	2.15	7.60	8.1	30.1
8	34,337	17.20			.851	8.49	9.88	2.25	7.85	8.1	29.8
9	30,943	17.80			.872	9.37	9.94	2.48	6.97	8.1	27.5
1950	29,826	26.40			.893	8.58	9.59	2.61	6.06	8.2	30.4
1	30,633	27.90			.879	8.14	9.60	2.68	6.41	8.3	26.1
2	31,982	15.90			.882	7.92	9.38	2.75	8.05	8.3	32.0
3	31,900	13.90			.901	7.82	9.12	2.95	6.62	8.3	33.4
4	31,356	14.90			.947	7.54	8.56	3.05	5.92	8.5	34.0
5	31,582	14.20			.948	7.77	8.85	3.06	6.20	8.6	35.6
6	31,157	15.00			.954	7.93	9.10	3.08	6.11	8.5	34.2
7	30,654	19.20			.944	8.13	9.39	3.03	6.25	8.4	34.1
8	31,217	20.10			.975	7.80	9.26	2.92	7.61	8.3	33.4
9	32,606	16.50			.967	7.76	9.52	2.86	8.30	8.4	34.7
1960	33,170	14.60			.950	7.41	10.15	2.90	9.18	8.6	34.0
1	32,725	13.00			.958	7.45	9.92	2.99	10.85	8.5	36.0
2	30,969	14.60			.954	7.85	10.18	3.24	9.73	8.4	36.0
3	29,176	14.10			.974	7.77	10.20	3.58	9.01	8.5	36.1
4	27,116	15.90			.908	8.35	10.57	3.98	7.06	8.4	35.8
5	25,127	19.70	241,590	104.01	.932	8.74	10.49	4.34	6.72	8.5	35.9
6	24,734	19.70	229,020	108.00	.942	7.84	10.54	4.40	7.53	8.5	37.2
7	23,953	19.10	219,500	109.13	.925	8.27	10.98	4.54	7.71	8.6	37.6
8	22,223	22.00	208,180	106.75	.945	8.05	10.94	4.92	7.18	8.6	36.5
9	21,350	24.80	194,590	109.72	.933	8.55	11.34	5.15	7.13	8.5	35.5
1970	20,423	23.60	179,580	113.73	.965	8.02	11.00	5.50	7.80	8.4	38.7
1	19,686	22.90	170,190	115.67	.950	7.67	11.25	5.82	9.08	8.4	38.8
2	18,710	26.30	161,840	115.61	.972	7.56	11.77	6.30	9.44	8.4	39.7
3	17,724	32.70	152,450	116.26	.950	8.32	12.46	6.86	9.82	8.2	39.2
4	16,394	30.40	145,260	112.86	.946	7.68	13.64	7.79	5.23	8.2	38.3
5	14,512	37.20	135,330	107.23	.976	7.78	13.83	9.07	5.11	8.3	37.0
6	13,346							9.58			

1/ Derived from USDA Statistics.

Table 8. Sheep Production Statistics for the 4 West Coast States 1/

Year	All Sheep Inv. Jan. 1 1000	Ave. value per head end of year $	No. of sheep farms	Ave. no. sheep/ farm	Lambs per ewe	Sheep deaths of sheep inv. %	Lambs deaths of lamb crop %	Ratio no. of cattle to sheep begin. of year	Ratio value of cattle to sheep (end of year)	Ave. fl. wt. lbs.
1940										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1950										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1960	3,319					7.44	6.76			
1	3,160					6.99	7.97			
2	3,024					7.01	7.81			
3	2,846					6.89	8.03			
4	2,650					7.74	8.94			
5	2,529		15,900	159.06	.946	8.11	9.27			
6	2,395		14,700	162.92	.951	7.10	9.90			
7	2,334		13,600	171.62	.954	6.86	9.16			
8	2,244		12,500	179.52	.949	7.80	10.18			
9	2,078	29.34	12,100	171.74	.925	8.18	10.26	3.85	6.60	7.9
1970	1,999	29.01	11,300	176.90	.951	7.55	8.97	3.98	7.11	7.7
1	1,900	28.25	10,800	175.93	.952	7.05	10.58	4.17	7.71	8.0
2	1,775	30.78	10,600	167.45	.954	7.38	11.37	3.80	8.21	8.6
3	1,674	37.43	9,900	169.09	.979	7.77	11.95	4.69	9.50	8.2
4	1,734	35.97	9,400	184.47	.946	7.38	11.31	4.81	5.25	7.8
5	1,607	44.16	9,600	167.40	.953	7.47	12.57	5.19	5.17	
6	1,540									

1/ Derived from USDA Statistics.

Table 9. Sheep Production Statistics for the 8 Western Intermountain States 1/

Year	All Sheep Inv. Jan. 1 1000	Ave. value per head end of year $	No. of sheep farms	Ave. no. sheep/ farm	Lambs per ewe	Sheep deaths of sheep inv. %	Lambs deaths of lamb crop %	Ratio no. of cattle to sheep begin. of year	Ratio value of cattle to sheep (end of year)	Ave. fl. wt. lbs.
1940										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1950										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1960	10,730					7.69	8.83			
1	10,376					7.51	9.04			
2	9,995					7.50	9.33			
3	9,890					6.89	8.03			
4	9,407					8.62	11.40			
5	8,933		20,060	445.31	.892	9.27	11.75			
6	8,769		18,830	465.69	.916	7.22	10.16			
7	8,505		18,100	469.89	.896	8.43	11.18			
8	8,037		17,380	462.43	.923	7.49	10.91			
9	7,909	28.80	16,860	469.82	.909	9.00	12.00	1.66	6.25	9.6
1970	7,705	27.47	16,340	471.54	.921	7.70	12.03	1.76	6.78	9.6
1	7,461	25.10	15,920	468.66	.917	7.73	12.34	1.88	8.40	9.6
2	7,132	30.08	15,400	463.12	.925	7.88	13.19	2.18	8.73	9.6
3	6,874	36.23	14,470	475.05	.889	9.62	15.22	2.17	9.27	9.4
4	6,232	33.72	13,380	465.77	.940	8.44	15.69	2.45	4.69	9.4
5	5,581	41.21	12,360	451.54	.923	9.48	16.79	2.69	4.79	
6	5,159									

1/ Derived from UDSA Statistics.

Table 10. Sheep Production Statistics for the Southwest - Texas 1/

Year	All Sheep Inv. Jan. 1 1000	Ave. value per head end of year $	No. of sheep farms	Ave. no. sheep/ farm	Lambs per ewe	Sheep deaths of sheep inv. %	Lambs deaths of lamb crop %	Ratio no. of cattle to sheep begin. of year	Ratio value of cattle to sheep (end of year)	Ave. fl. wt. lbs.
1940										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1950										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1960	5,938					9.43	12.36			
1	6,140					10.42	11.55			
2	5,854					11.19	13.50			
3	5,538					10.83	10.56			
4	5,185					10.61	10.08			
5	4,539		19,500	232.77	.782	10.80	8.26			
6	4,795		19,000	252.37	.741	9.91	8.49			
7	4,802		18,800	255.43	.750	8.96	11.29			
8	4,228		18,500	228.54	.790	9.46	10.55			
9	4,029	19.00	16,000	251.81	.800	8.69	9.12	2.89	7.16	7.4
1970	3,708	17.50	15,000	247.20	.920	8.60	7.34	3.29	8.30	7.6
1	3,789	18.50	14,500	261.31	.840	6.97	7.57	3.32	10.00	7.3
2	3,524	20.00	13,500	261.04	.910	5.96	7.08	3.82	11.50	7.1
3	3,214	26.00	12,500	257.12	.850	5.91	6.11	4.78	10.96	7.0
4	3,090	23.50	11,000	280.91	.702	6.47	9.00	5.26	5.53	7.1
5	2,688	31.50	9,500	282.95	.884	3.72	6.47	6.18	4.92	
6	2,600									

1/ Derived from USDA Statistics.

Table 11. Sheep Production Statistics for the 8 West North Central States 1/

Year	All Sheep Inv. Jan. 1 1000	Ave. value per head end of year $	No. of sheep farms	Ave. no. sheep/ farm	Lambs per ewe	Sheep deaths of sheep inv. %	Lambs deaths of lamb crop %	Ratio no. of cattle to sheep begin. of year	Ratio value of cattle to sheep (end of year)	Ave. fl. wt. lbs.
1940										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1950										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1960	7,505					5.58	11.40			
1	7,702					5.42	10.59			
2	7,205					7.50	9.33			
3	6,560					5.71	10.96			
4	6,039					6.36	11.10			
5	5,554		81,910	67.81	1.027	6.45	11.60			
6	5,343		77,720	68.75	1.031	7.02	11.49			
7	5,009		74,720	67.04	1.041	7.75	12.14			
8	4,583		69,720	65.73	1.058	7.48	11.54			
9	4,320	23.45	63,920	67.58	1.044	7.38	12.61	7.99	7.82	8.7
1970	4,108	21.91	57,900	71.95	1.048	7.94	13.02	8.57	8.31	8.4
1	3,857	22.15	55,120	69.97	1.057	7.87	13.01	9.34	9.61	8.5
2	3,742	26.11	51,820	72.21	1.069	8.04	13.70	9.96	9.85	8.5
3	3,588	31.51	49,200	72.93	1.074	7.32	13.27	10.61	10.74	8.3
4	3,145	27.61	46,320	67.90	1.128	7.02	14.94	12.81	5.56	8.3
5	2,643	32.86	42,520	62.16	1.109	7.88	15.40	14.93	5.72	
6	2,217									

1/ Derived for USDA Statistics.

Table 12. Sheep Production Statistics for the 5 East North Central States 1/

Year	All Sheep Inv. Jan. 1 1000	Ave. value per head end of year $	No. of sheep farms	Ave. no. sheep/ farm	Lambs per ewe	Sheep deaths of sheep inv. %	Lambs deaths of lamb crop %	Ratio no. of cattle to sheep begin. of year	Ratio value of cattle to sheep (end of year)	Ave. fl. wt. lbs.
1940										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1950										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1960	3,073					6.41	10.19			
1	2,925					6.46	9.24			
2	2,790					6.81	8.67			
3	2,500					6.72	9.08			
4	2,259					7.26	7.94			
5	2,162		63,200	34.21	1.046	8.00	7.70			
6	2,091		60,600	34.50	1.037	7.56	7.99			
7	2,051		58,100	35.30	1.065	8.14	8.59			
8	1,949		55,735	34.97	1.056	7.90	10.10			
9	1,889	20.88	53,200	36.51	1.041	7.94	9.97	6.80	9.88	7.9
1970	1,819	19.66	49,124	37.03	1.039	8.36	10.22	7.08	10.64	8.0
1	1,663	19.51	45,600	36.47	1.069	8.00	9.58	7.86	11.94	7.9
2	1,574	23.74	43,600	36.10	1.078	8.09	10.33	8.44	11.52	7.9
3	1,478	29.66	41,400	35.70	1.063	9.54	10.61	9.03	11.73	7.9
4	1,350	29.19	40,800	33.09	1.044	8.30	12.67	9.99	6.88	7.9
5	1,214	32.64	38,900	31.21	1.087	7.91	14.16	11.50	7.44	
6	1,119									

1/ Derived from USDA Statistics.

Table 13. Production Statistics for the 6 Mideast States 1/

Year	All Sheep Inv. Jan. 1 1000	Ave. value per head end of year $	No. of sheep farms	Ave. no. sheep/ farm	Lambs per ewe	Sheep deaths of sheep inv. %	Lambs deaths of lamb crop %	Ratio no. of cattle to sheep begin. of year	Ratio value of cattle to sheep (end of year)	Ave. fl. wt. lbs.
1940										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1950										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1960	1,514					8.19	12.95			
1	1,398					7.30	11.87			
2	1,167					7.88	11.73			
3	988					7.69	11.89			
4	811					9.25	12.16			
5	698		17,220	40.53	1.109	10.32	12.03			
6	672		15,620	43.02	1.098	9.48	12.16			
7	631		14,470	43.61	1.099	9.08	12.31			
8	577.5		14,030	41.16	1.103	9.89	13.55			
9	533.4	21.33	12,750	34.53	1.070	8.31	14.08	25.98	6.52	7.0
1970	514	19.39	11,490	36.35	1.073	8.48	14.12	28.04	8.22	6.9
1	465	21.19	10,370	37.14	1.066	9.35	14.05	31.42	8.89	7.0
2	431	24.77	9,510	38.32	1.113	7.24	13.72	35.44	9.21	6.8
3	401	29.45	8,760	38.25	1.134	9.10	15.49	39.52	9.62	6.7
4	368	29.70	8,210	39.03	1.139	7.42	13.01	45.51	4.70	6.6
5	342	34.02	7,260	40.36	1.158	8.61	14.30	55.93	4.66	
6	307									

1/ Derived from USDA Statistics.

Table 14. Production Statistics for the 6 Southeast States 1/

Year	All Sheep Inv. Jan. 1 1000	Ave. value per head end of year $	No. of sheep farms	Ave. no. sheep/ farm	Lambs per ewe	Sheep deaths of sheep inv. %	Lambs deaths of lamb crop %	Ratio no. of cattle to sheep begin. of year	Ratio value of cattle to sheep (end of year)	Ave. fl. wt. lbs.
1940										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1950										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1960	249					8.64	16.60			
1	229					9.30	16.75			
2	178.8					10.96	18.32			
3	158.5					12.18	18.47			
4	126.8					14.43	20.57			
5	105.6		4,060	26.01	.782	17.71	26.01			
6	94.2		3,650	25.81	.741	13.80	23.67			
7	79.8		3,250	24.55	.760	13.16	20.87			
8	70.6		2,970	23.77	.767	10.48	20.60			
9	61.3	13.56	2,810	21.81	.758	8.16	22.46	168.60	10.26	5.4
1970	54.3	16.52	2,590	20.97	.749	6.26	16.55	193.43	8.79	5.6
1	49.9	17.50	2,380	20.97	.783	9.62	18.82	215.27	9.88	5.6
2	47.9	18.65	2,130	22.49	.789	8.77	20.61	227.87	11.86	5.7
3	41.8	24.72	1,930	21.66	.845	9.57	20.00	269.16	10.92	5.7
4	39.4	25.05	1,710	23.04	.934	9.64	23.43	300.96	5.21	5.8
5	35.5	26.96	1,600	22.19	.869	10.99	21.23	383.43	5.13	
6	31.3									

1/ Derived for USDA Statistics.

Table 15. Production Statistics for the 12 Northeastern States 1/

Year	All Sheep Inv. Jan. 1 1000	Ave. value per head end of year $	No. of sheep farms	Ave. no. sheep/ farm	Lambs per ewe	Sheep deaths of sheep inv. %	Lambs deaths of lamb crop %	Ratio no. of cattle to sheep begin. of year	Ratio value of cattle to sheep (end of year)	Ave. fl. wt. lbs.
1940										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1950										
1										
2										
3										
4										
5										
6										
7										
8										
9										
1960	842					8.35	10.95			
1	795.4					8.42	11.06			
2	755.4					9.15	10.09			
3	695.9					8.05	10.44			
4	637.6					8.94	9.93			
5	606.2		19,740	30.71	1.070	8.97	9.44			
6	569.7		18,900	30.14	1.065	9.20	10.24			
7	541.5		18,390	29.44	1.073	9.27	10.27			
8	533.7		17,480	30.53	1.068	9.46	10.77			
9	530.6	20.97	16,950	31.30	1.052	9.54	11.29	10.42	11.80	7.0
1970	520.8	20.47	15,940	32.67	1.049	9.25	11.97	10.62	12.76	6.9
1	501.2	20.38	15,500	32.34	1.047	9.98	11.80	10.68	13.64	6.8
2	484.3	23.91	14,710	32.92	1.038	9.70	11.85	11.04	13.35	6.8
3	452.9	31.78	14,270	31.79	1.103	10.86	13.76	11.78	12.39	6.8
4	435.5	31.90	14,440	30.16	1.073	9.62	12.33	12.53	8.36	6.7
5	401.7	35.14	13,590	29.56	1.078	10.53	12.57	14.30	8.57	
6	372.9									

1/ Derived for USDA Statistics.